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Full-Scale Demonstration of Open Tank Oxygen Activated Sludge Treatment

Metropolitan Denver Sewage Disposal District No 1, CO

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Municipal Environmental Research Lab, Cincinnati, OH Wastewater Research Div

May 79

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16. ABSTRACT

This report presents an operating summary of a full-scale demonstration of the FMC open tank pure oxygen (FMC O_2) activated sludge system, conducted at the facilities of the Metropolitan Denver Sewage Disposal District No. 1 (Metro) in Denver, Colorado. The system was operated over a period of 15 mo at both steady state and diurnal flow rates ranging from 22,700 m^3/day (6 mgd) to 53,000 m^3/day (14 mgd), with average F/M loadings varying between 0.49 and 1.14 kg BOD/day/kg MLVSS and clarifier overflow rates ranging from 16.5 to 32.2 m^3/day/m^2 (406 to 791 gpd/ft^2).

The overall performance of the system was dictated in large part by the quantity of filamentous organisms in the activated sludge, and the investigation of these organisms, with attempts to control or eliminate them, was an ongoing activity during much of the demonstration.

The system was evaluated as to oxygen transfer efficiency and oxygen consumption. Further, it was compared to the Metro diffused air system running in parallel with the demonstration system on the basis of sludge production and power requirements. Comparison of sludge settleabilities was made between these two systems and a closed tank pure oxygen system (UNOX) also in operation at Metro.

In addition to allowing an evaluation of the FMC O_2 system as a whole, the demonstration provided an opportunity to evaluate various component equipment items as to their reliability and performance.

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then died off. It appears to be an acid producing relative of Sphaerotilus. It also appears to be the filamentous organism responsible for the high SVI values found in the mixed liquor samples last winter.

Fungus

The fungus colony counts on the raw sewage, secondary influent, and mixed liquor samples were higher than is usual for sewage and activated sludge. Also, an unusually high proportion of fungi which produce either arthrospores or blastospores were found. However, the fungus counts were approximately one tenth of the fungus counts I have found in mixed liquor when it was clear that the fungi were growing in the system and interfering with the settling characteristics of the sludge.

Actinomycetes

Actinomycete colony counts were in the normal range for sewage and mixed liquor samples except for the Marox pilot plant sample of February 23. That sample showed a mixed liquor consisting largely of actinomycetes. Otherwise there was no indication that the actinomycetes were causing a continuing problem in either system.

Conclusion

A variety of different types of filamentous organisms are present in both activated sludge systems. Most of the filamentous organisms are present in the raw sewage and in the secondary influent as well as in the mixed liquor. The fungi may be partially responsible for the poor flocculation observed but are not present in high enough numbers to interfere with the settling characteristics of the sludge. Actinomycetes could cause settling problems if a long sludge residence time were used but this is not usually the case. The filamentous bacteria present appear to be microaerophylic and appear to grow more vigorously in the air system than in the oxygen system. The filamentous bacterium which appears to be the most likely cause of high SVI values is an acid-producing, sheathed organism which has not been previously described.

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Agency

Municipal Environmental Research
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FULL-SCALE DEMONSTRATION OF OPEN TANK OXYGEN ACTIVATED SLUDGE TREATMENT

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report presents design details, operating experiences, and all operating and performance data for the first full-scale demonstration of an open tank pure oxygen activated sludge wastewater treatment system. Consideration of the oxygenation technology discussed herein is recommended for design engineers, facilities planners, and potential municipal users.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

This report presents an operating summary of a full-scale demonstration of the FMC open tank pure oxygen (FMC O_2) activated sludge system, conducted at the facilities of the Metropolitan Denver Sewage Disposal District No. 1 (Metro) in Denver, Colorado. The system was operated over a period of 15 mo at both steady state and diurnal flow rates ranging from 22,700 m^3/day (6 mgd) to 53,000 m^3/day (14 mgd), with average F/M loadings varying between 0.49 and 1.14 kg BOD/day/kg MLVSS and clarifier overflow rates ranging from 16.5 to 32.2 m^3/day/m^2 (406 to 791 gpd/ft^2).

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In addition to allowing an evaluation of the FMC O2 system as a whole, the demonstration provided an opportunity to evaluate various component equipment items as to their reliability and performance.

This report was submitted in fulfillment of Grant No. S803910 by the Metropolitan Denver Sewage Disposal District No. 1 under the partial sponsorship of the U. S. Environmental Protection Agency. This report covers the operational period of June 1, 1976, to September 7, 1977.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BOD -- biochemical oxygen demand, 5 day
BOD_A -- BOD applied
BOD_R -- BOD removed
cm -- centimeter
COD -- chemical oxygen demand
COD_R -- COD removed
D.O. -- dissolved oxygen
Eff -- effluent
EPA -- U. S. Environmental Protection Agency
FAD -- fixed active diffuser
F/M -- food/microorganism ratio
ft -- foot
g -- gram
gal -- gallon
gpm -- gallons per minute
gpd -- gallons per day
hp -- horsepower
hr -- hour
in. -- inch
Inf -- influent
kg -- kilogram
kgf -- kilograms, force
kWh -- kilowatt hour
l -- liter
lb -- pound
m -- meter
mA -- milliampere
mg -- milligram
mgd -- million gallons per day
mil gal -- million gallons
min -- minute
MLSS -- mixed liquor suspended solids
MLVSS -- mixed liquor volatile suspended solids
mo -- month
No. -- number
psig -- pounds per square inch, gauge
RAD -- rotating active diffuser
rpm -- revolutions per minute
SRT -- solids retention time

SS -- suspended solids
SVI -- sludge volume index
TKN -- total Kjeldahl nitrogen
TOC -- total organic carbon
TOC_R -- TOC removed
VSS -- volatile suspended solids

SYMBOLS

$CaCO_3$ -- calcium carbonate
I-P -- current-to-pneumatic
NH_4^+-N -- ammonium nitrogen
NO_2^--N -- nitrite nitrogen
NO_3^--N -- nitrate nitrogen
O_2 -- oxygen
Q -- influent wastewater flow
R -- return sludge flow

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SECTION 1

INTRODUCTION

PROJECT BACKGROUND

The development of high efficiency open tank oxygenation systems for wastewater treatment was begun in March 1971 with the establishment of a batch-mode pilot plant at the facilities of the Metropolitan Denver Sewage Disposal District No. 1 (Metro). This first step in a joint research and development effort between Metro and the Martin Marietta Corporation was followed in July 1971 by a 7.6-l/min (2-gpm) flow-through pilot system to monitor substrate removal. For oxygen transfer, the system employed a fixed active diffuser (FAD), a device producing minute oxygen bubbles by the shearing action of a high velocity stream of water directed across porous diffusion surfaces. In September 1972, based on the recommendation of several consulting engineers, the system was scaled up to a 57-l/min (15-gpm) pilot plant, a size determined to be suitable for obtaining design data for existing plant expansion or new plant construction. In January 1973, 6 mo prior to completion of the 57-l/min (15-gpm) study, the oxygenation process was sold by the Martin Marietta Corporation to FMC Corporation, which continued the research investigation with the Metro staff. Results from the 57-l/min (15-gpm) pilot study indicated the following:

1. Efficient oxygen mass transfer using the FAD,
2. Satisfactory treatment performance at nominal detention times of 1 to 2 hr,
3. Effective system operation at a wide range of F/M ratios (0.2 to 1.2 kg BOD/day/kg MLVSS), and
4. Efficient control of supplied oxygen through the use of D.O. sensors, analyzers, and controllers.

Concurrent with the above program, two EPA funded research and development studies were being conducted on open tank oxygenation systems: 1) a 114-l/min (30-gpm) activated sludge pilot program, testing the FAD at the City of Englewood, Colorado Wastewater Treatment Plant (October 1972 - July 1974) (1) and 2) a comparison of pure oxygen versus diffused air for the aerobic stabilization of waste activated sludge at Metro (November 1972 - May 1974) (2).

The success of the 57-l/min (15-gpm) pilot study at Metro resulted in a scale up of the system to a 1900-m^3/day (0.5-mgd) facility to verify the performance of the FAD on a large scale. A major objective of this project was the investigation of a flotation phenomenon observed in all previous testing with the FAD, a phenomenon wherein solids rose to the surface of the mixed liquor basin to produce a concentrated sludge layer (float). This study, from January 12 through April 16, 1974, indicated that float could be continuously generated in mixed liquors having both high ($\geq$ 4000 mg/l) and low ($\approx$2600 mg/l) concentrations of suspended solids. It was also ascertained that removal of the float, which averaged 6.5 percent total solids, could supply up to 50 percent of the total system wasting requirements.

The development by FMC engineers of an improved device for achieving small bubble diffusion led to the next phase of the research and development effort. This device, a rotating active diffuser (RAD), differed from the FAD in that oxygen bubble shear was produced by rotating the diffuser through the liquid medium, rather than by pumping liquid across the diffusion surfaces. Substitution of the RAD for the FAD in the 57-l/min (15-gpm) pilot system indicated that the RAD produced oxygen transfer efficiencies comparable to those obtained with the FAD, but with lower power requirements for equivalent oxygen transfer. As a result, a full-scale RAD prototype unit was installed in an aerobic digestion basin at Metro for further testing. This study verified that high oxygen mass transfer and utilization efficiencies could be realized, and that the mixing characteristics of the RAD were sufficient to keep sludge solids uniformly mixed. The prototype unit operated continuously for 3 mo in unscreened waste activated sludge without any major problems or hardware failures. The success of development efforts to this point led Metro and the FMC Corporation to submit a request to the EPA on March 19, 1975, for a grant to demonstrate the open tank oxygenation system in full-scale operation at the Metro facilities.

PURPOSE OF THE PROJECT

As outlined to the EPA in the grant request, the objectives of the project were as follows:

1. To convert a three-pass, diffused air activated sludge system to a single-pass, open tank oxygenation system and evaluate the operation of this system at varying F/M ratios, detention times, and ambient temperature conditions.

2. To provide the data base necessary for the design of either a partial or total conversion of the existing Metro diffused air system to open tank oxygenation. This data base would include oxygen utilization efficiency, solids settling characteristics, power requirements for oxygen dissolution, and the reliability of diffusion and oxygen control equipment.

3. To provide EPA an opportunity to demonstrate on a large scale a pure oxygen open tank treatment system previously researched on a smaller scale.

4. To provide EPA with data for technology transfer purposes related to other activated sludge treatment systems that might benefit from the upgrading of an existing facility.

SECTION 2

CONCLUSIONS

A three-pass, diffused air mixed liquor basin was modified for the installation of a single-pass FMC O_2 system which employed RAD's for oxygen dissolution and dissolved oxygen sensors for control of oxygen flow to the basin. In the absence of filamentous organisms, the system provided satisfactory treatment performance at average oxygenation times of 1.2 to 1.9 hr based on influent flow, at F/M ratios ranging from 0.7 to 1.1 kg BOD/day/kg MLVSS, and with mixed liquor suspended solids (MLSS) concentrations between 2700 and 3940 mg/l.

Filamentous organisms in the activated sludge resulted in the deterioration of the system performance with respect to sludge settleability during much of the demonstration. These organisms were also present in the parallel operating Metro diffused air system, though to a lesser degree, and may have been introduced into both systems by one of the primary effluent streams feeding the Metro secondary. Oxygen system performance was excellent during the last 3½ mo of operation, with no adverse effects due to filamentous organisms.

Effluent soluble BOD values averaging 4 mg/l throughout the demonstration indicated efficient mixed liquor basin performance with respect to BOD removal. Poor clarification was responsible for those high effluent BOD values encountered.

Adequate mixing of the mixed liquor basin contents was demonstrated by both suspended solids and dissolved oxygen profiles of the basin.

The system evidenced minimal nitrification operating at oxygenation times of 1.2 to 2.7 hr based on influent flow and SRT's of 3.5 to 10 days based on total system inventory.

Tests conducted during the demonstration showed oxygen transfer efficiencies in excess of 96 percent at or below the design oxygen flow rate. Efficiencies in excess of 92 percent were obtained at oxygen flow rates up to 25 percent above design.

Solids production during the operation of the oxygen system was equivalent to that obtained from the parallel operating air system, at comparable SRT's.

Oxygen consumption averaged 1.23 kg O_2/kg BOD_R under what were considered normal operating conditions. Periods of long SRT, low BOD removal, and oxygen system equipment problems exhibited somewhat higher values for oxygen consumption.

The calculated power required for the operation of the oxygen system averaged 39 percent below that required for the parallel operating air system, based on equivalent flow rates and BOD removals.

SECTION 3

RECOMMENDATIONS

The oxygen system was operated at average clarifier overflow rates up to 32.6 m^3/day/m^2 (800 gpd/ft^2). For most of the time, overflow rates were less than 24.4 m^3/day/m^2 (600 gpd/ft^2). The performance of the system should be evaluated at higher clarifier overflow rates.

The maximum treatment capacity of the system was never determined because of hydraulic limitations of the mixed liquor basin. This capacity should be ascertained in future studies.

Additional cold weather operating data would be desirable in future studies to demonstrate the capability of the system.

Future studies, if possible, should investigate the difference in the growth rates of filamentous organisms in the FMC O_2 system as compared to a diffused air system.

In future operations, where modification of process operating variables fails to alleviate filamentous sludge conditions, consideration should be given to the use of continuous low-dose chlorination for filamentous control (3). The reported chlorine dosage of 2 to 3 kg/1000 kg MLVSS/day equates, for an MLVSS level of 3000 mg/l and an oxygenation time of 1.5 hr based on influent flow, to a chlorine dosage of 0.38 to 0.56 mg/l (3.1 to 4.7 lb/mil gal) of influent flow.

During this demonstration, an accumulation of floating solids (float) concentrated on the surface of the mixed liquor. Further studies should evaluate the controlled removal of float to produce a waste sludge of high solids concentration.

The dewatering characteristics of oxygen activated sludge should be investigated.

The use of FMC rotating active diffusers to provide oxygen where needed for the maintenance of dissolved oxygen levels in existing diffused air activated sludge systems should be studied.

The feasibility of single-stage nitrification using the FMC O_2 system alone or together with a diffused air system should be evaluated.

SECTION 4

FACILITIES

TREATMENT PLANT DESCRIPTION

Completed in 1966, the original Metro treatment complex consisted of a 106,000-m^3/day (28-mgd) primary treatment facility and a 371,000-m^3/day (98-mgd) conventional aeration activated sludge system, the latter designed to receive both the effluent from the Metro primary process and 265,000 m^3/day (70 mgd) of primary treated sewage from the City of Denver's North Side (DNS) Wastewater Treatment Plant. Solids processing facilities consisted of a dissolved air flotation system for activated sludge concentration and vacuum filters for the dewatering of the concentrated waste activated sludge, Metro's primary sludge, and anaerobically digested sludge from the DNS treatment plant.

Rapid growth in the Metro area caused the plant to exceed design capacity by 1973. Construction of additional primary and secondary treatment capacity and sludge processing facilities began in 1974 and was completed in 1976. The additional treatment facilities included a 159,000-m^3/day (42-mgd) primary treatment system and a 273,000-m^3/day (72-mgd) closed tank pure oxygen activated sludge facility (UNOX). Anaerobic digesters were provided for sludge stabilization. With the facilities expansion, the treatment plant has been subdivided into two treatment complexes, North (original facilities) and South (new facilities) (Figure 1).

OXYGEN SYSTEM INSTALLATION

The Metro North Complex secondary treatment facility consists of 12 three-pass aeration basins and associated clarifiers. The basins are grouped into four quadrants, each containing three adjacent basins feeding, individually or through a common channel, into three secondary clarifiers. For reasons of access it was decided to install the demonstration equipment in the first pass ("A" pass) of aeration basin No. 11 and to use clarifier No. 11 for the final settling tank in the initial phases of the project. The general site plan for the demonstration is shown in Figure 2.

Several modifications of the existing facilities were required for the installation of the oxygen system. First, since only the "A" pass of the three-pass aeration basin was to be used for the demonstration, it was necessary to install a 137-cm (54-in.) bypass duct to allow for a direct connection from the discharge end of "A" pass to the venturi outlet in "C" pass feeding the clarifier. Second, although a control gate was available to isolate the feed

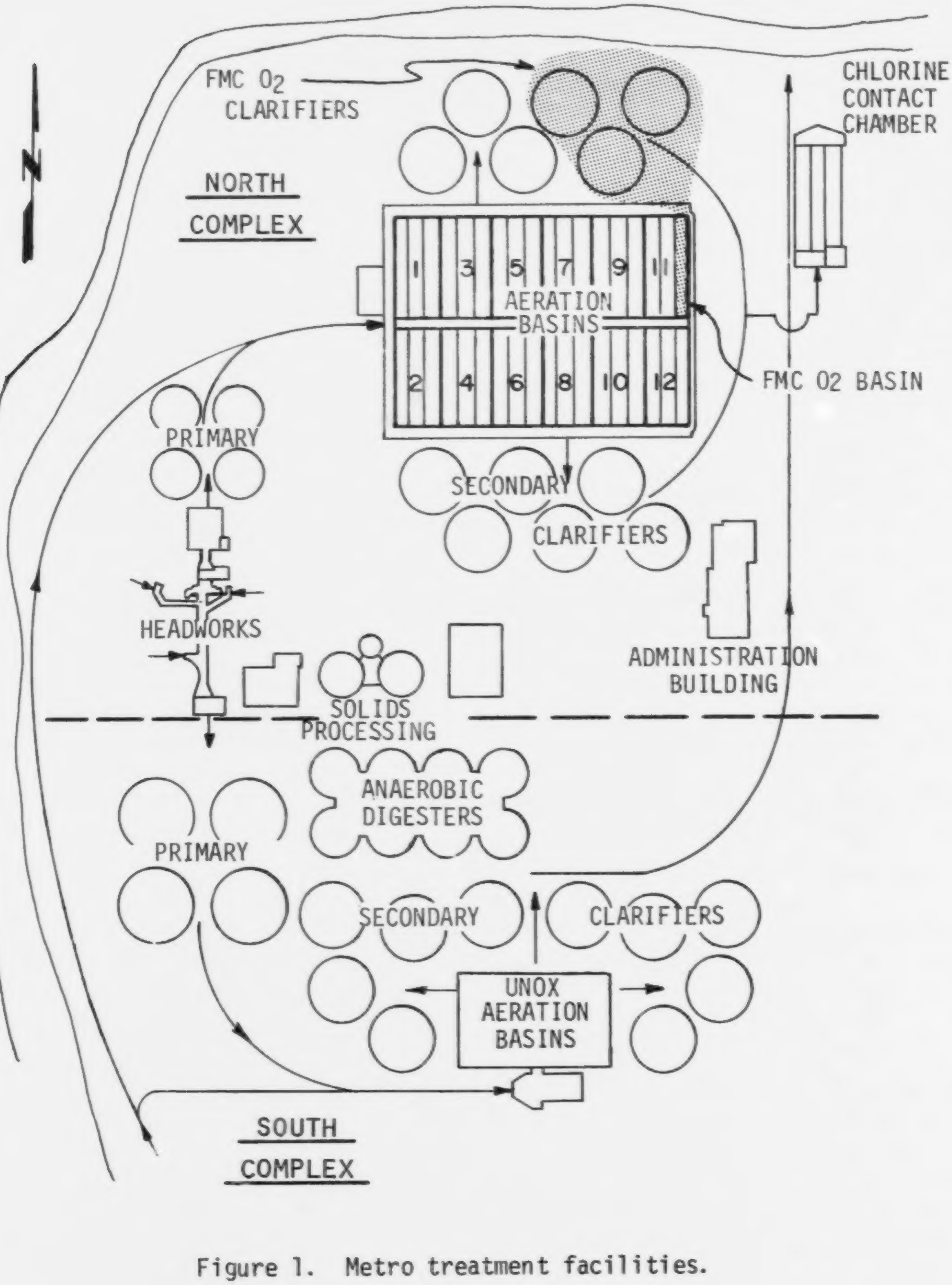

Figure 1. Metro treatment facilities.

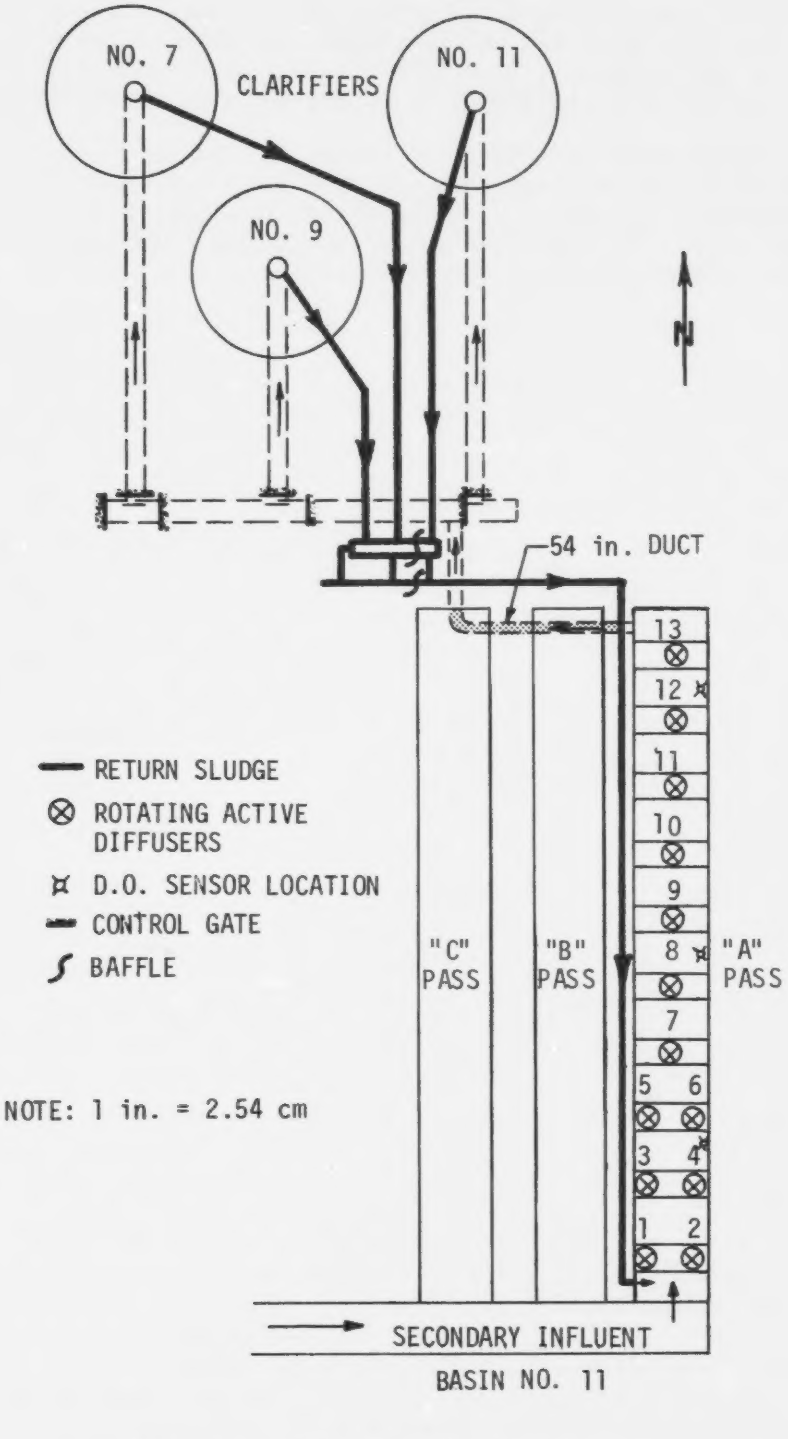

Figure 2. Demonstration site plan.

from the mixed liquor basin to clarifier No. 11, the existing facility did not allow segregation of the return sludge from that of the other clarifiers operating in the quadrant. To accomplish this, baffles were installed in the return sludge wet well and pump line to prevent sludge interchange.

The mixed liquor basin and clarifier chosen for the demonstration are depicted in Figure 3. Fluctuating somewhat with the liquid level in the secondary influent channel, the capacity of the mixed liquor basin was a nominal 2500 m^3 (661,000 gal). The clarifier was of the center-feed type with three rows of overflow effluent weirs at the periphery.

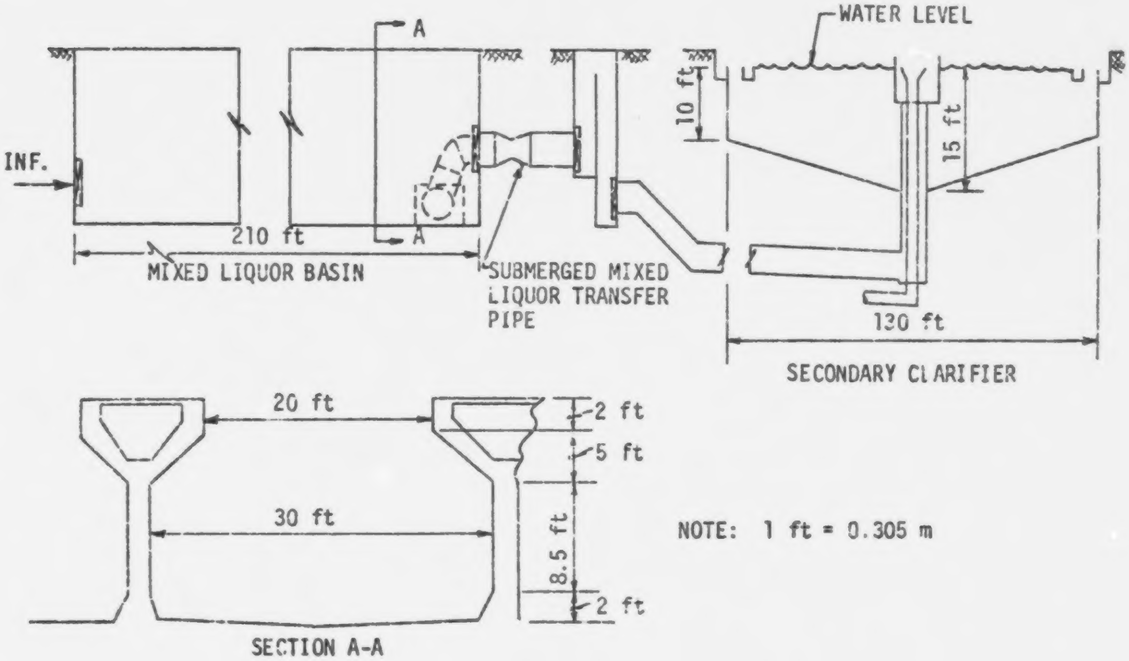

Figure 3. Dimensional layout of mixed liquor basin and clarifier.

Ten bridges were installed spanning "A" pass to accommodate the installation of the 13 RAD's used for the demonstration. Two RAD's were mounted on each of the first three bridges at the influent end of the basin, with a single RAD on each of the other bridges. The greater number of RAD's at the influent end of the basin were provided to meet the anticipated oxygen demand in this area. A dissolved oxygen (D.O.) sensor located in the basin between bridges 2 and 3 was used to regulate, through a control system, the flow of oxygen to the first six RAD's. The next four RAD's were similarly controlled by a D.O. sensor located between bridges 5 and 6, and the last three RAD's by a third D.O. sensor located between bridges 9 and 10. Each D.O. sensor provided a 4-20 mA signal proportional to the measured D.O. level; this signal was coverted by an I-P transducer to a pneumatic signal in the control system. The input signals from the three D.O. sensors were compared to individual set points on a control panel, and return pneumatic signals were conveyed to flow control valves which modulated the oxygen flow to each of the three controlled areas of the basin.

Liquid oxygen, supplied by an outside vendor, was stored in a 42-m^3 (11,000-gal) dewar from which it was vaporized to a gas by ambient heat exchangers for transmission to the system. Signals were transmitted to a control center from an orifice plate and temperature and pressure sensors installed downstream of the vaporizer. These signals were translated in the control system to both instantaneous and totalized oxygen flow readings on the control panel. Gauges on the panel also monitored oxygen temperature and pressure. Dissolved oxygen analyzers and recorders were provided to monitor D.O. levels at the three sensor positions in the basin, with alarm systems installed to indicate high or low D.O. conditions. A schematic of a typical FMC O_2 installation is shown in Figure 4.

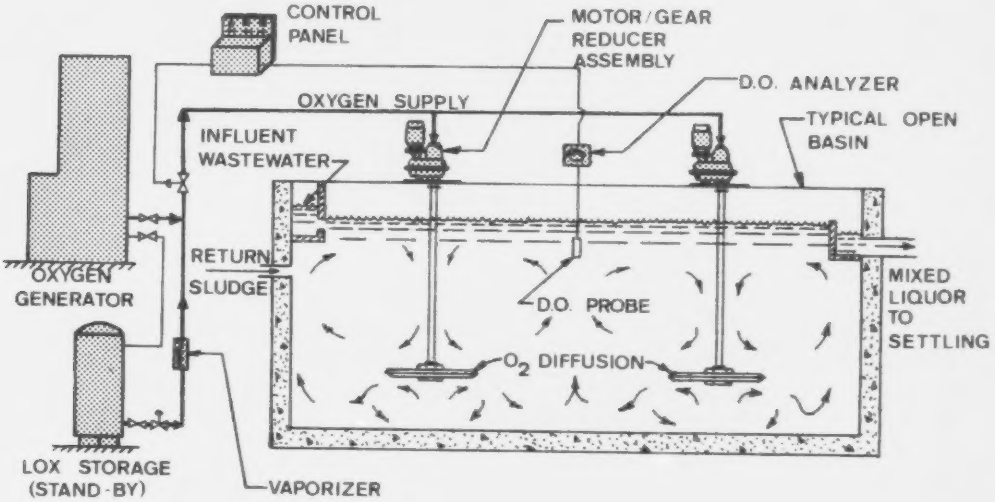

Figure 4. A typical FMC O2 installation.

Thirteen RAD's were used to provide efficient oxygen transfer in the mixed liquor basin. The equipment was sized to accommodate a nominal flow of 46,900 m^3/day (12.4 mgd) and a BOD loading of 7030 kg/day (15,500 lb/day). Principle elements of the RAD are shown in Figures 5 and 6. The RAD con-

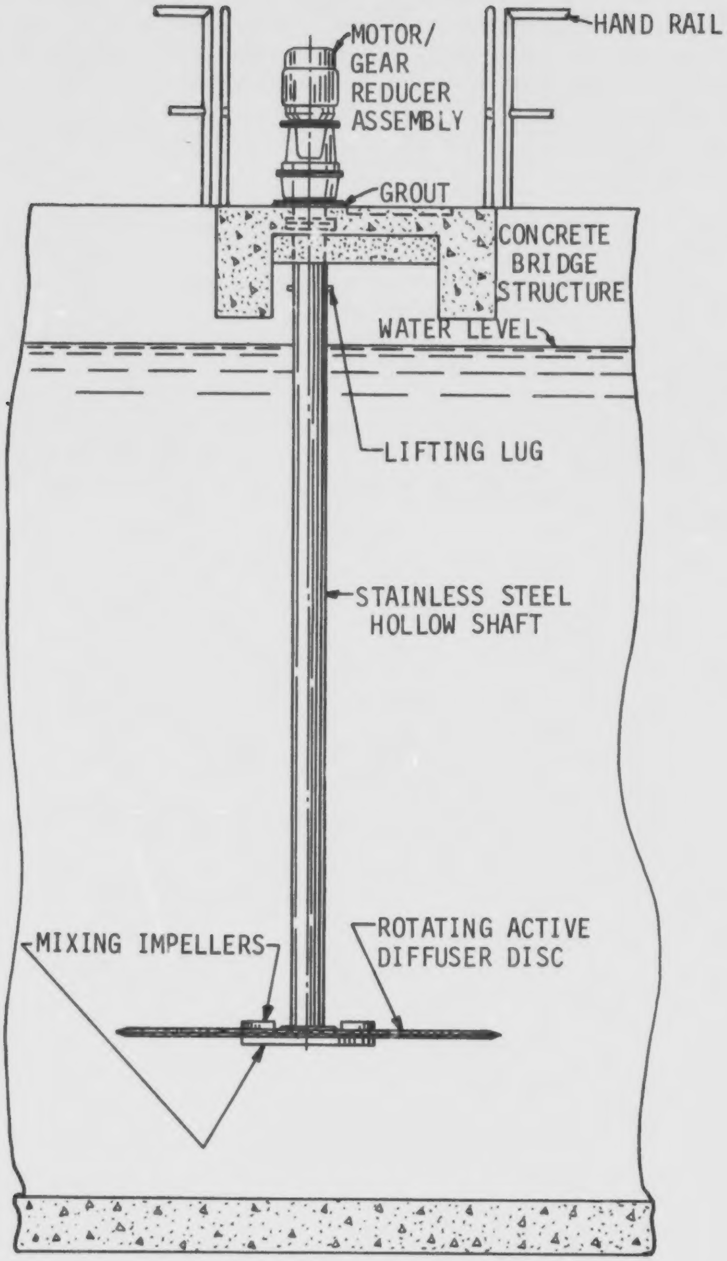
HAND RAIL
MOTOR/ GEAR REDUCER ASSEMBLY
GROUT
CONCRETE BRIDGE STRUCTURE
WATER LEVEL
LIFTING LUG
STAINLESS STEEL HOLLOW SHAFT
MIXING IMPELLERS
ROTATING ACTIVE DIFFUSER DISC

Figure 5. Elevation view of rotating active diffuser (RAD) and drive assembly.

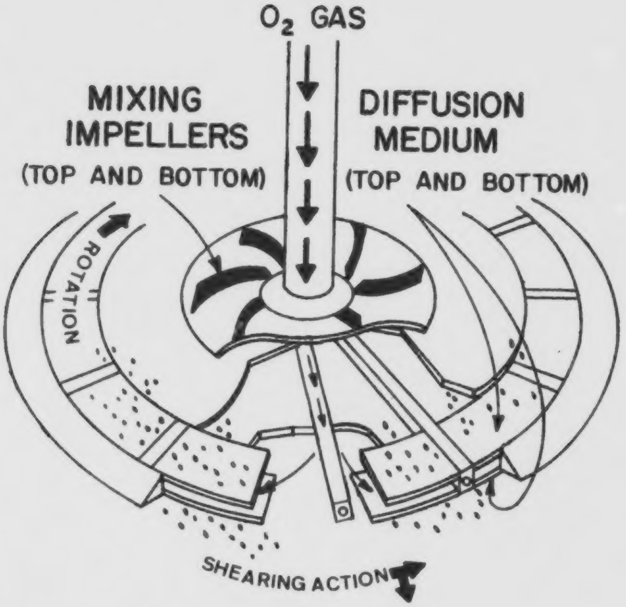
O$_2$ GAS
MIXING IMPELLERS (TOP AND BOTTOM)
DIFFUSION MEDIUM (TOP AND BOTTOM)
ROTATION
SHEARING ACTION

Figure 6. Section view of RAD diffusion media and impellers.

sists of a 2.1-m (7-ft) diameter submerged rotating disc, located approximately 0.9 m (3 ft) above the oxygenation tank floor and mounted to a 16.8-cm (6.625-in.) diameter hollow shaft. Twelve diffusion assemblies, each consisting of upper and lower ceramic plates epoxied into a plastic frame 20.3 cm (8 in.) wide, are installed in sections near the periphery of the disc forming circular diffusion bands on both the upper and lower surfaces adjacent to the tapered edge of the disc. Radial impellers are mounted on the top and bottom surfaces of the disc to provide shear for small-bubble formation, solids mixing, and oxygen distribution into the mixed liquor. The disc and shaft are rotated by a gear drive operating at an output speed between 82 and 86 rpm. Oxygen is transferred from the supply line to the hollow shaft via a rotating seal and is distributed from the shaft at the disc interface by radial lines leading to the diffusion assemblies. Oxygen gas from the supply system is provided to the basin at pressures of 21,100 - 24,600 kgf/m^2 (30 - 35 psig). As the oxygen gas emerges from the ceramic plates in the diffusion assemblies, the rotation of the disc and the radial flow of mixed liquor shear the oxygen bubbles to produce minute bubbles in the 50 - 200 micron range. The micron-size bubble is essential for the oxygen absorption rate required for efficient oxygen transfer into the liquid medium. The tapered edge of the disc prevents turbulence which would cause coalescence of the bubbles.

Modification of the existing facility and installation of equipment was accomplished within a 2-mo period prior to startup of the project. Figure 7 shows the demonstration system in operation at the Metro plant. Figure 8 is a view of the mixed liquor basin with RAD's installed prior to startup.

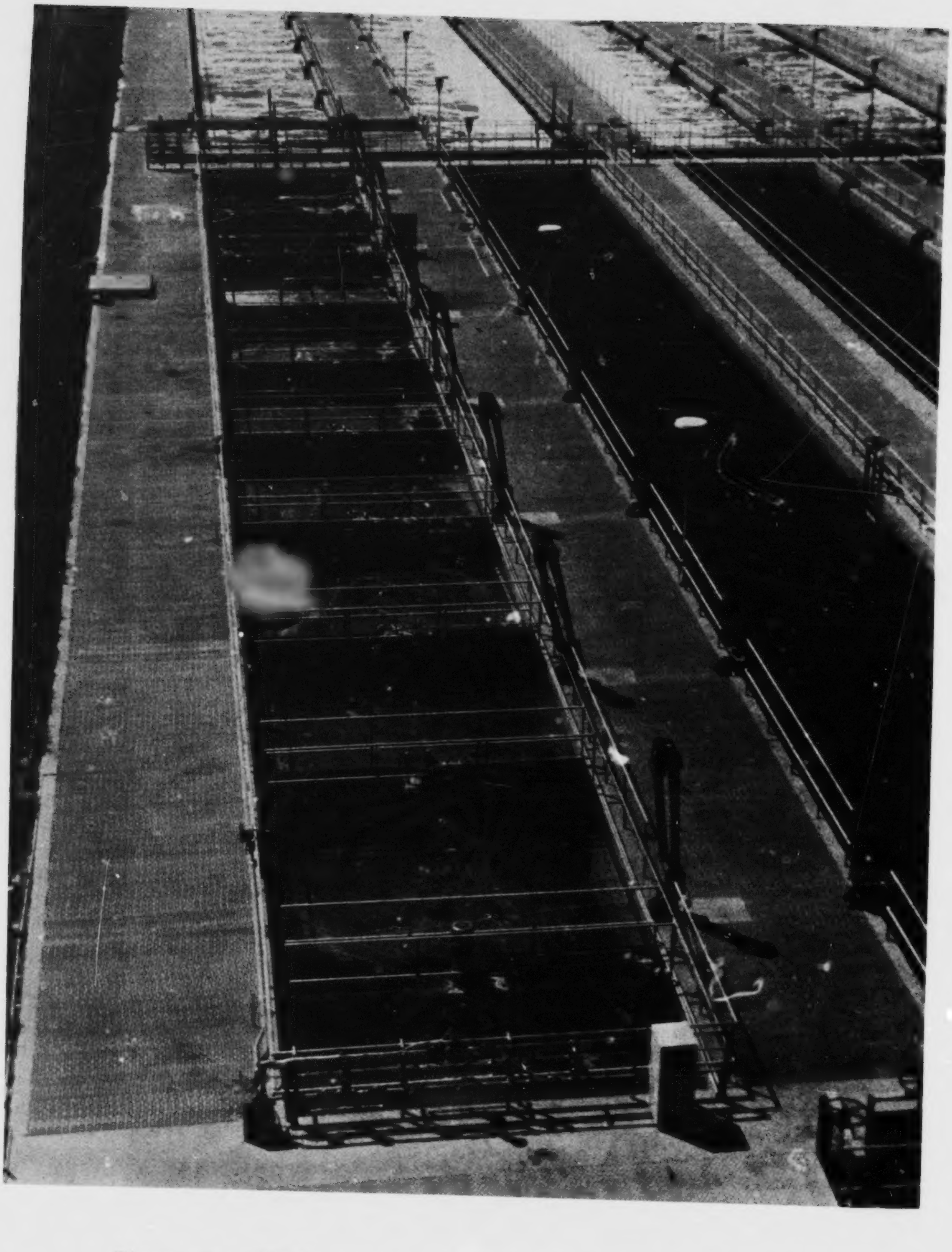

Figure 7. FMC O_2 system in operation at the Metro plant.

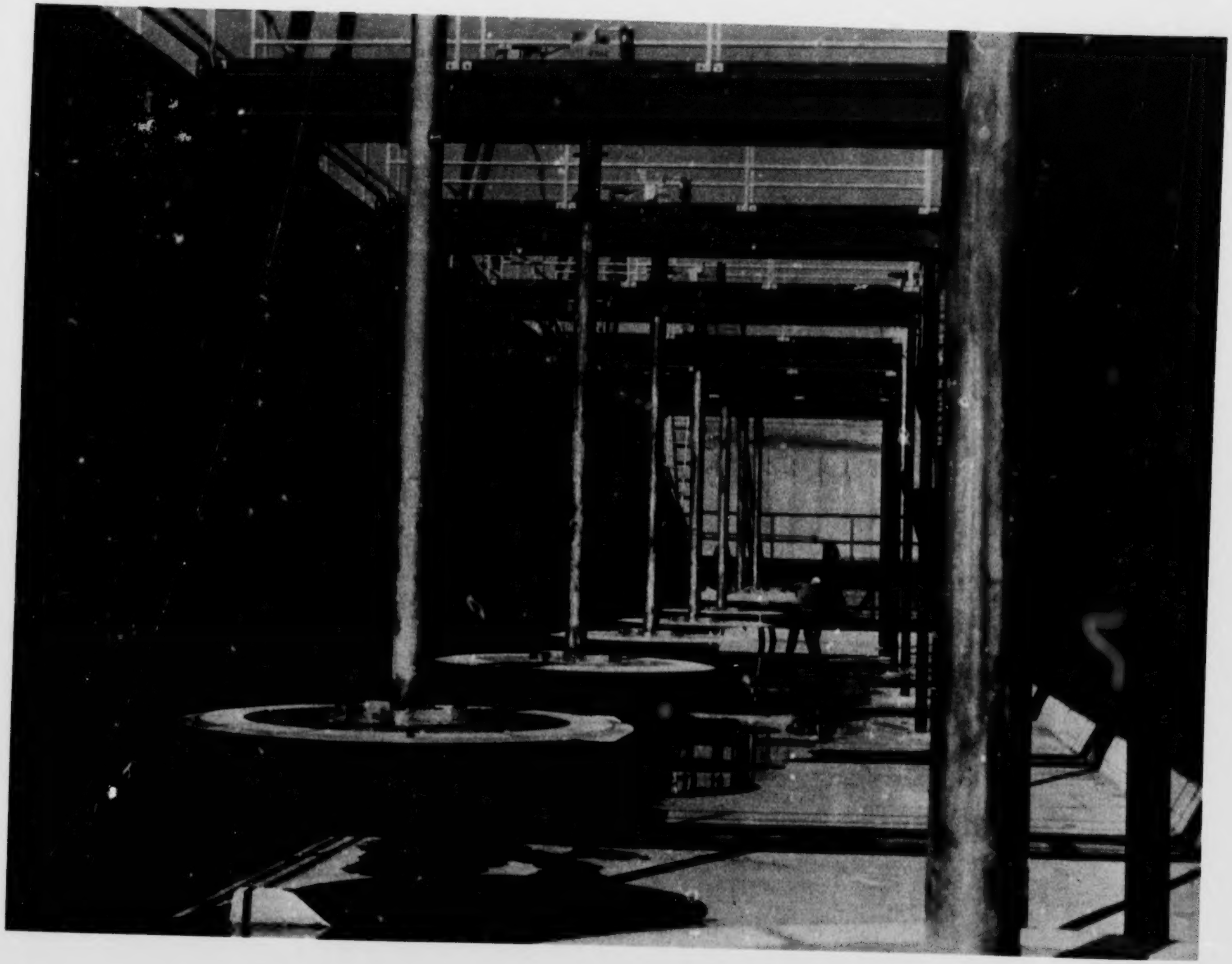

Figure 8. Mixed liquor basin with RAD's installed.

SECTION 5

PROCESS MONITORING

Metering, recording, and totalizing devices were used to monitor the influent flow, return and waste sludge flows, and the supply of oxygen fed to the aeration basin. Dissolved oxygen levels in the basin were continuously monitored at three locations by installed D.O. sensors checked daily, and calibrated as required, against a portable D.O. meter. pH values were initially obtained in the laboratory on daily composites of the influent and effluent samples and weekly mixed liquor grab samples, but carbon dioxide losses and resultant pH changes during sample transportation and storage dictated the advisability of making in situ pH determinations. Beginning December 26, 1976, these measurements were made daily using a portable pH meter. Mixed liquor temperature readings were taken in situ twice daily. Clarifier sludge blanket measurements were taken six times per day using a portable blanket finder. Initially, settling tests (unstirred SVI) on the mixed liquor were performed daily. This frequency was expanded to twice per day on December 26, 1976, and expanded again to include twice per day stirred SVI determinations from March 8, 1977, onward. Centrifuge spins of the return sludge, checked frequently against laboratory suspended solids results, were used to facilitate real-time sludge wasting, and twice daily turbidity measurements of the final effluent provided immediate system performance evaluation.

Twenty-four hr composite samples of the influent, effluent, mixed liquor, and return sludge (equivalent to waste sludge) samples were collected by refrigerated automatic samplers for laboratory analysis. Samples making up the composites were taken at 20-min intervals and were not proportioned for flow. Because of biological growth fouling the inlet line of the effluent sampler, automatic sampling at this location was discontinued on May 30, 1977, in favor of a manual sampling procedure, with grab samples every 2 hr making up each daily composite.

Daily laboratory analyses included total and volatile suspended solids on influent, effluent, mixed liquor, and return sludge samples, as well as BOD and TOC on the influent and effluent. Influent and effluent nitrogen forms, as well as influent and mixed liquor alkalinity levels, were determined weekly, the latter on grab samples delivered to the laboratory. Initially, nitrate nitrogen analysis of the effluent was performed on composite samples, but the procedure was changed to grab sample analysis after May 30, 1977, due to elevated nitrate levels produced by a nitrifying bacteria culture in the effluent sampler inlet line. Soluble BOD analyses were run on influent and effluent samples twice weekly until May 4, 1977, and daily thereafter. Filamentous counts and general microscopic examinations of the mixed liquor were performed at least twice per week over the course of the project.

SECTION 6

ANALYTICAL PROCEDURES

Suspended solids analyses were performed in accordance with Standard Methods (4), a fiberglass overlay atop the standard filter being employed as a modification to aid in filtration. Five-day biochemical oxygen demand (BOD) was determined by the membrane electrode method (4). Samples analyzed for soluble BOD were filtered through a 0.45 micron membrane filter prior to analysis. TOC determinations were made on a Dohrman Envirotech DC-50 carbon analyzer (5). COD determinations were made in accordance with Standard Methods (4). Nitrate-nitrite nitrogen was determined by the automated cadmium reduction technique (4). Ammonia and total Kjeldahl nitrogen forms were determined using the automated phenate method (5), samples for Kjeldahl analysis being digested in a Technicon Block Digester prior to analysis. Alkalinity was determined by potentiometric titration to pH 4.5 on a Brinkmann Autotitrator (4). Settling tests (SVI), both stirred and unstirred, were determined in 2-liter Mallory Settleometers (6). Stirred SVI tests were performed using a device consisting of two opposed vertical rods moving adjacent to the settleometer wall at a motor-driven speed of 1 rpm. Counts of filamentous organisms in the mixed liquor were made on Gram stain smears of approximately diluted samples examined microscopically.

SECTION 7

PROCESS OPERATION AND PERFORMANCE

The demonstration project began on March 30, 1976, and terminated on September 7, 1977. The period from March 30 through the end of May 1976 was a startup period during which personnel involved with the project were familiarizing themselves with the equipment and a general electrical, mechanical, and pneumatic shakedown of the system was performed. The balance of the project has been divided into seven operating phases, summarized in Table 1.

TABLE 1. PHASE SUMMARY

Phase	Period*	No. of Days	Nominal Influent Flow (mgd)	Flow Pattern	No. of Clarifiers
I	6/1/76 - 6/30/76	30	9	Steady State	1
	7/1/76 - 7/31/76	31			
	8/1/76 - 8/31/76+	26			
II	9/1/76 - 9/28/76	28	6	Steady State	1
	10/7/76 - 10/31/76	25			
	11/1/76 - 11/21/76	21			
III	12/26/76 - 1/31/77•	36	6	Steady State	1
	3/8/77 - 3/28/77	21			
IV	3/29/77 - 5/4/77	37	10	Diurnal	2
V	5/5/77 - 6/6/77	33	12	Diurnal	2
VI	6/7/77 - 7/4/77	28	14	Diurnal	2
	7/5/77 - 8/4/77	31			
VII	8/5/77 - 9/7/77	34	12	Diurnal	2

* Division of phases into periods made on the basis of temporary shutdowns, or arbitrarily to create roughly 1-mo operating periods.

+ 8/25/76 - 8/29/76, system shutdown.

• 1/20/77, system shutdown.

Initially, the project outline called for division of the demonstration into operating phases based upon both steady state and diurnal flow patterns at different flow rates. Although this regime has been adhered to in this report, it is important to note that in Phases II and III, flow conditions, rather than being planned, were dictated by operating difficulties as described below. These two phases show identical operating parameters in Table 1; however, a division has been made because Phase III was actually an investigative phase instituted in an attempt to overcome operating difficulties experienced in Phase II.

The various phases of operation and interim periods of project shutdown are described in the following discussion. A summary of operating performance data is shown in Table 2, with the operating parameters in Table 3. A complete daily record of the operating performance of the system can be seen in Appendix A.

PHASE I (JUNE 1 - AUGUST 31, 1976)

The flow during this phase was steady state, averaging 34,400 m^3/day (9.1 mgd). The first operating period, from June 1 to June 30, was characterized by a sludge quality which yielded the best settling characteristics encountered over the course of the project, an average unstirred SVI of 79 ml/g. Effluent quality during this period averaged 30 mg/l suspended solids (SS). This level of solids in the effluent was attributed to a failure of the rapidly settling sludge to sweep pin-point floc from suspension. In mid-July, SVI's began to increase, with values exceeding 100 ml/g for the first time. As a result, the return sludge solids concentrations began to decrease and sludge blanket levels in the clarifier began to rise. By mid-August, SVI values were averaging in excess of 200 ml/g and sludge bulking was a common occurrence, the principle contributor to an average 60 mg/l SS in the effluent for the month of August. MLSS levels, which had averaged 3070 mg/l during the month of June, decreased to an average of 2180 mg/l in August. Due to poor effluent quality from August 11 through 13, the flow through the system was reduced over the next 6 days from 35,200 m^3/day (9.3 mgd) to 26,900 m^3/day (7.1 mgd) in an effort to improve performance. Although effluent quality did improve, sludge settling characteristics remained unchanged.

It was noted during this time that the high SVI values were very closely tied to an increase in the population of filamentous organisms that were appearing in the activated sludge. Figure 9 illustrates this relationship as observed during the demonstration. In brief, the filamentous organisms observed were slender, straight to slightly curved filaments generally ranging in length between 30 and 200 microns and appeared to be outgrowths of sludge floc particles (Figure 10). These organisms were gram-negative, unbranched and unsheathed, with individual cells approximately 0.5 microns in diameter by 1.0 - 1.5 microns in length. Microbiologists from both Metro and EPA concurred on the morphological description of the organism as being of bacterial rather than fungal origin and on the fact that it was not a Sphaerotilus type, although no serious attempt was made to identify it.

Over the next several months, a major effort was made to investigate possible causes of the filamentous growth and methods for controlling it. The data

TABLE 2. PERFORMANCE DATA

Phase	Period	Flow (mgd)•	Oxygenation Time (hr)		Influent (mg/l)					Effluent (mg/l)					Removals (%)+			
			Q	Q + R	SS	VSS	BOD	TOC	COD*	SS	VSS	BOD	TOC	COD*	SS	BOD	TOC	COD*
I	6/1/76 - 6/30/76	9.53	1.66	1.19	88	68	126	87	276	30	23	19	29	87	65	85	66	67
	7/1/76 - 7/31/76	9.45	1.68	1.20	84	69	116	83	263	26	22	23	25	75	68	81	70	71
	8/1/76 - 8/31/76	8.22	1.93	1.32	93	75	116	87	276	60	52	36	37	111	36	69	58	60
II	9/1/76 - 9/28/76	6.08	2.61	1.70	85	69	119	85	269	26	21	19	22	66	63	83	72	73
	10/7/76 - 10/31/76	5.76	2.75	1.72	93	75	129	93	295	16	12	9	18	54	85	93	80	82
	11/1/76 - 11/21/76	5.89	2.69	1.62	96	78	128	97	307	48	39	18	29	87	44	85	68	70
III	12/26/76 - 1/31/77	6.35	2.50	1.50	108	91	160	118	374	79	65	43	46	138	24	73	60	62
	3/8/77 - 3/28/77	6.20	2.69	1.37	108	92	169	122	387	19	16	16	28	84	83	90	77	78
IV	3/29/77 - 5/4/77	9.78	1.70	1.14	105	88	159	121	384	41	36	31	41	123	61	81	66	68
V	5/5/77 - 6/6/77	12.06	1.38	0.89	105	89	149	113	358	30	24	23	31	93	72	84	72	73
VI	6/7/77 - 7/4/77	13.62	1.22	0.82	110	92	142	107	339	15	13	13	25	75	86	91	77	78
	7/5/77 - 8/4/77	14.29	1.17	0.79	99	77	106	83	263	17	13	12	22	66	84	89	73	75
VII	8/5/77 - 9/7/77	12.30	1.36	0.90	122	98	132	102	323	17	14	13	23	69	86	90	78	79

• 1 mgd = 3785 m^3/day

* COD values are calculated quantities based on TOC. Influent COD = 3.17 (± 0.27) TOC and effluent COD = 3.00 (± 0.44) TOC factors are based upon 25 and 26 determinations, respectively, over the course of the project.

+ Removals calculated from total pounds, influent minus effluent.

TABLE 3. OPERATING PARAMETERS

		Mixed Liquor							Return Sludge		Basin Loadings		Clarifier Loadings		Solids Retention Time	
Phase	Period	Recycle, R/Q (%)	SS (mg/l)	VSS (mg/l)	Unstirred SVI (ml/g)	DO (mg/l)	Temp. (°C)	pH*	SS (mg/l)	VSS (mg/l)	F/M $\left(\frac{\text{kg BOD/day}}{\text{kg MLVSS}}\right)$	Organic $\left(\frac{\text{lb BOD/day}}{1000\ ft^3}\right)^{o}$	Overflow, Q $(gpd/ft^2)^{+}$	Mass, Q + R $\left(\frac{\text{lb SS/day}}{ft^2}\right)^{**}$	Aer. Inv. (days)	Tot. Inv. (days)
I	6/1/76 - 6/30/76	40	3,070	2,530	79	2.7	20	-	11,000	9,120	0.72	113	791	25.8	2.2	4.8
	7/1/76 - 7/31/76	40	2,700	2,260	95	5.2	21	-	10,300	8,530	0.75	104	785	22.5	1.9	5.4
	8/1/76 - 8/31/76	49	2,180	1,810	194	2.1	22	-	7,930	6,600	0.82	89	682	16.7	1.4	4.3
II	9/1/76 - 9/28/76	59	2,840	2,330	242	1.1	22	-	7,290	6,260	0.50	69	505	16.3	4.2	9.8
	10/7/76 - 10/31/76	60	2,870	2,310	210	3.7	21	-	7,230	5,860	0.49	70	478	16.8	5.1	9.6
	11/1/76 - 11/21/76	67	2,520	2,100	278	4.3	20	-	5,840	4,870	0.56	71	489	15.4	2.4	5.7
III	12/26/76 - 1/31/77	69	2,820	2,320	208	3.1	16	6.6	6,500	5,470	0.67	96	527	18.9	2.1	4.7
	3/8/77 - 3/28/77	88	3,250	2,620	176	3.8	15	6.7	6,740	5,490	0.59	94	514	23.8	2.7	4.9
IV	3/29/77 - 5/4/77	43	2,380	1,980	264	4.4	17	6.6	7,530	6,300	1.14	140	406	10.5	1.0	3.8
V	5/5/77 - 6/6/77	48	2,870	2,370	150	5.9	19	6.7	7,890	6,600	1.10	161	501	16.1	1.1	3.5
VI	6/7/77 - 7/4/77	43	3,370	2,800	113	3.7	20	6.8	10,500	8,960	1.00	173	566	20.6	1.2	3.9
	7/5/77 - 8/4/77	41	3,870	3,080	102	2.8	22	6.8	13,300	10,700	0.71	136	594	23.7	1.5	4.0
VII	8/5/77 - 9/7/77	43	3,940	3,130	94	2.2	22	6.6	14,300	11,400	0.75	145	511	21.9	1.5	3.4

* Median values reported.

° 1 lb/day/1000 ft^3 = 0.0160 kg/day/m^3

+ 1 gpd/ft^2 = 0.0407 m^3/day/m^2

** 1 lb/day/ft^2 = 4.88 kg/day/m^2

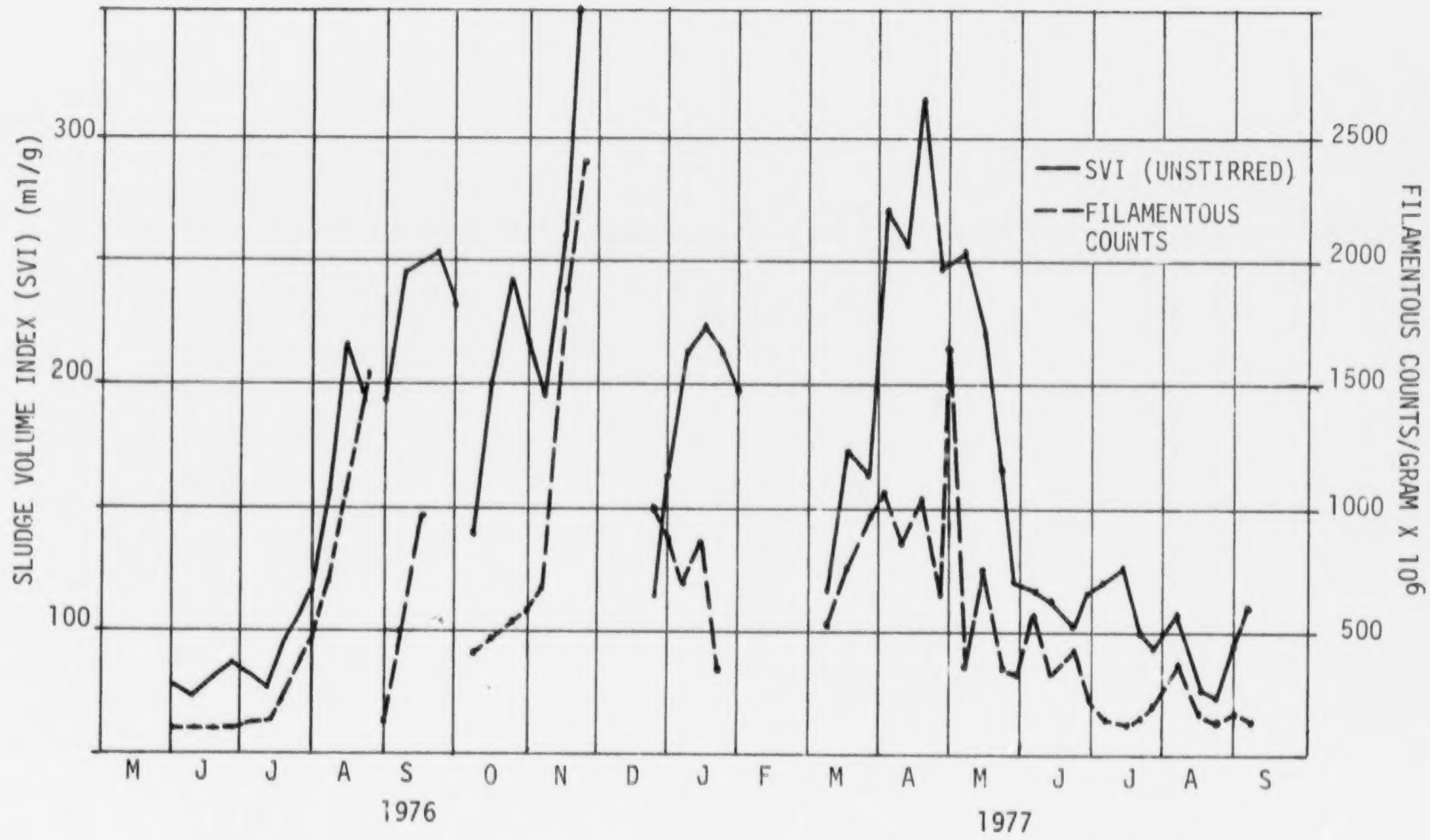

Figure 9. Relationship of SVI to filamentous counts.

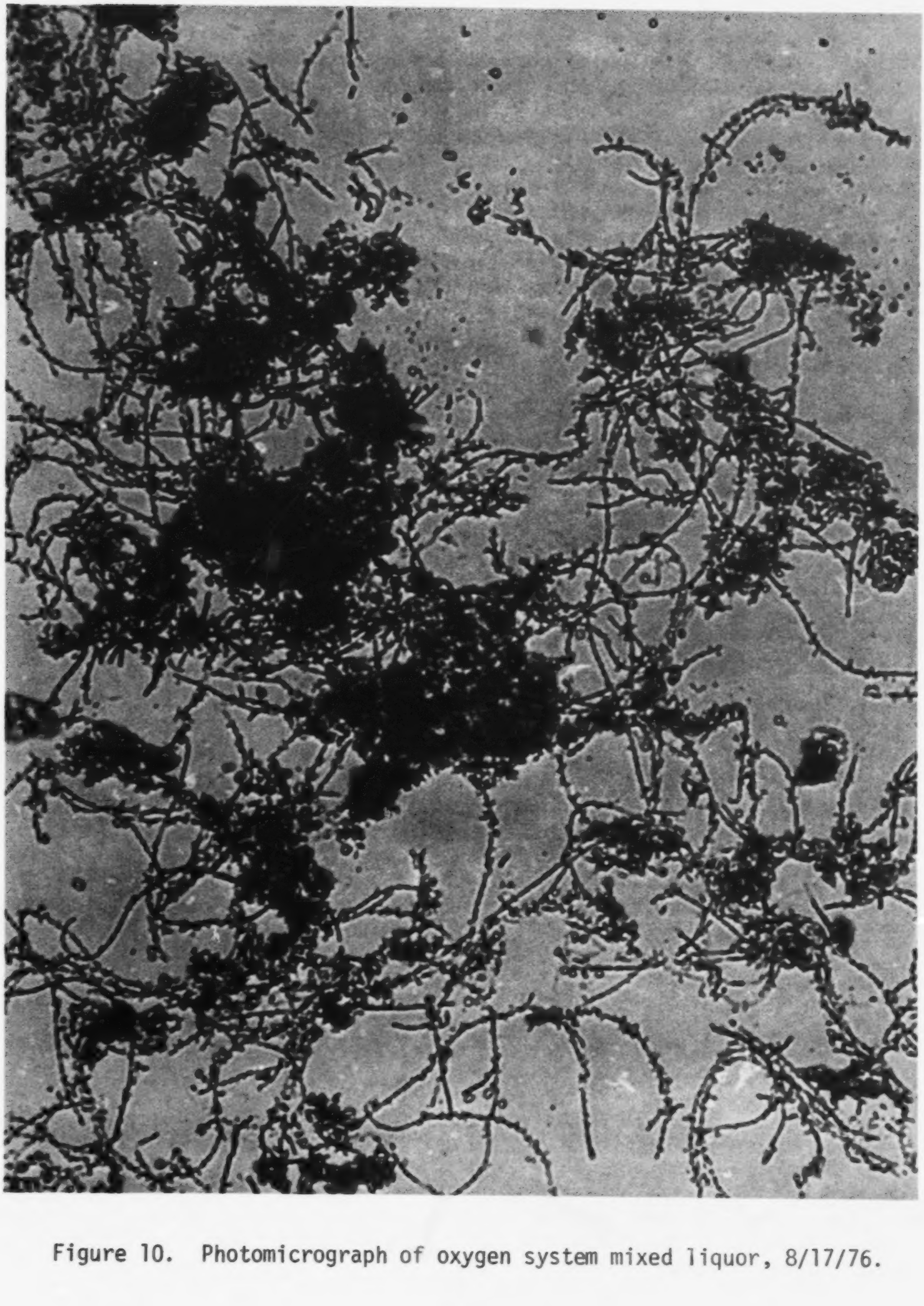

Figure 10. Photomicrograph of oxygen system mixed liquor, 8/17/76.

from the latter part of July indicated that high mixed liquor D.O. levels (> 10 mg/l), resulting from malfunctioning D.O. sensors, coincided with the proliferation of filamentous organisms, a relationship previously reported (7). On August 18, the D.O. set point for the mixed liquor was reduced to 1 ± ½ mg/l to evaluate the effects on the filamentous population. This evaluation continued until August 24 when it became apparent that the filamentous situation was not improving. As a result, a decision was made to empty the basin for a new startup.

Over the course of Phase I, effluent quality averaged 38 mg/l SS and 26 mg/l BOD at an average F/M loading of 0.76 kg BOD/day/kg MLVSS. Clarifier overflow rates averaged 30.8 $m^3/day/m^2$ (756 gpd/ft^2).

Float accumulation in the mixed liquor basin was in evidence during the first operating phase. This float material, varying in depth up to 38 cm (15 in.), averaging approximately 6 percent total solids and containing high concentrations of Nocardia, was first noted in the basin on April 25 during the startup period. Since no provision had been made for the removal of float from the basin, attempts were made beginning in May to re-entrain the float into the mixed liquor. A float screw*, water sprays, surface mixers, and an air-lift pump were all unsuccessful in re-entraining the float. On July 3, a downdraft pump** was installed near the outlet end of the basin, followed on August 4 by a second downdraft pump located near the center of the basin. With the two downdraft pumps in operation, re-entrainment was only partial and float was still present on the surface of the mixed liquor. It should be noted that at no time during the demonstration was any float present on the surface of the clarifier.

PHASE II (SEPTEMBER 1 - NOVEMBER 21, 1976)

After dumping the system at the conclusion of Phase I, it was decided to use a seed sludge from aeration basin No. 12 for the next startup to accelerate establishment of the system. This sludge was chosen because it evidenced a minimal population of filamentous organisms***.

Despite the reseeding of the system and the continuation of the low D.O. level control begun in August, the filamentous sludge condition and resultant high SVI values experienced in Phase I continued to persist. Operating under steady state hydraulic conditions, the average flow of 22,300 m^3/day (5.9 mgd) reflected the inability of the system to sustain a higher hydraulic loading without adversely affecting effluent quality. In analyzing the Phase I data, it was evident that periods of high F/M ratios occurred, with values up to 1.5 kg BOD/day/kg MLVSS being attained. High F/M ratios have been cited in the literature as a possible cause contributing to filamentous conditions (3, 8, 9). Flow rates, which started out greater than 30,300 m^3/day (8 mgd) at the beginning of Phase II, were gradually decreased in an effort to reduce the F/M loading to approximately 0.5 kg BOD/day/kg MLVSS. No improvement in sludge quality was observed, and further flow reductions to 11,400 m^3/day (3 mgd) by the end of the first operating period of Phase II were necessary to maintain effluent quality. Unstirred SVI values averaged 242 ml/g for the month of September, and the effluent quality of 26 mg/l SS and 19 mg/l BOD for September was maintained by reducing influent flows in an attempt to offset the poor sludge settleability.

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* A helical screw mounted around a diffuser shaft to auger floating materials downward into the mixed liquor.

** A shrouded propeller mounted vertically in the mixed liquor basin designed to draw material from the liquid surface over the shroud and through the propeller to exit near the bottom of the basin.

*** Filamentous cultures similar to those observed in the oxygen basin were observed in all the operating air system basins at Metro, although to a considerably lesser degree.

On September 28, the influent flow to the system was shut down in order to evaluate a period of aerobic digestion for controlling filamentous proliferation, an approach suggested by a pilot study conducted at the City of Englewood, Colorado Wastewater Treatment Plant. After 42 hr of aerobic digestion of the mixed liquor, during which an 11,400-m^3/day (3-mgd) return sludge flow was maintained, no improvement was seen in the filamentous condition. On September 30, it was decided to dump the contents of the system, clean the mixed liquor basin and clarifier, and restart the system. Startup was begun by seeding the mixed liquor basin with the Metro air system sludge exhibiting the best settling characteristics available on the plant site. The fill operation commenced on October 4, the system was stabilized by October 6, and data collection began on October 7. At this startup, mixed liquor D.O. levels were raised to 3 mg/l to investigate the effect of a somewhat higher D.O. concentration on filamentous control (3, 8). The D.O. level was raised again on October 22 to approximately 5 mg/l and maintained at that level through November. In spite of the elevated D.O. levels, filamentous proliferation began shortly after the October startup, with a resultant increase in SVI's. October effluent quality, averaging 16 mg/l SS and 9 mg/l BOD, was achieved by holding flow rates at or below 22,700 m^3/day (6 mgd) for the entire period.

Much of November exhibited increasingly poor sludge settling characteristics, with return sludge and MLSS concentrations continuing to decrease. Effluent quality remained generally acceptable until an attempt was made, shortly before the end of the operating period, to increase the flow through the system from 22,700 m^3/day (6 mgd) to 26,500 m^3/day (7 mgd); this resulted in bulking conditions, leading to an average effluent quality of 48 mg/l SS and 18 mg/l BOD for the month. By November 21, filamentous counts and SVI values had reached such high levels that a decision was made to temporarily halt operations pending a coordination meeting at Metro with the EPA Project Officer and representatives of Metro and the FMC Corporation.

Overall performance for Phase II showed an average effluent quality of 26 mg/l SS and 15 mg/l BOD, at an average F/M loading of 0.51 kg BOD/day/kg MLVSS and a clarifier overflow rate of 20.0 m^3/day/m^2 (491 gpd/ft^2).

Float re-entrainment, unsuccessful in Phase I in keeping the mixed liquor basin surface free of float, was practiced intermittently during Phase II with similar results. However, re-entrainment began to come under increasing suspicion as being a possible cause of filamentous proliferation for two reasons: 1) The first occurrence of filamentous growth in the system came shortly after the installation of the first downdraft pump in July. The second and third system startups in late August and early October, in which re-entrainment was practiced virtually from the start, exhibited filamentous from the outset. 2) A brief interruption of the re-entrainment process during October appeared to result in an improvement in sludge floc characteristics. This was observed microscopically as a partial coating of the filaments with zoogleal mass. After resumption of float re-entrainment, further deterioration of the floc was noted.

INTERIM PERIOD (NOVEMBER 22 - DECEMBER 25, 1976)

In the coordination meeting of November 24, it was decided to investigate possible methods of eliminating the filamentous organisms from the activated sludge. Although chemical treatment was considered, it was thought to offer only a temporary remedy. Emphasis was placed instead on operational changes which might effect a lasting solution. To conserve project resources, laboratory monitoring during this interim period was to be limited to sludge quality determinations and those analyses required for sludge wasting; as such, this information has not been included in the data tables.

The prevailing hypothesis at this time was that the float material, still abundant on the surface of the mixed liquor, was responsible for causing the growth of the filamentous population. The coordination meeting outlined four approaches for subsequent investigation:

1. 100 percent skimming of float to waste,
2. 100 percent float re-entrainment,
3. Partial float re-entrainment plus float skimming, and
4. No re-entrainment or float skimming.

The system was restarted on December 4 by again seeding the mixed liquor basin with return sludge from one of Metro's aeration systems exhibiting good settling characteristics and relatively few filamentous organisms. An improvised float skimmer* was installed at the north end of the basin between bridges 9 and 10 in an attempt to skim the float from the surface. In addition, the two downdraft pumps previously installed continued to operate towards the outlet end of the basin in an effort to re-entrain the surface float. Despite these efforts, float removal was again only partial over the surface of the basin. The system was drained on December 15 when SVI values again rose into the 200 - 300 ml/g range.

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* The float skimmer consisted of a funnel mounted in an assembly which allowed the rim of the funnel to float near the liquid surface. The funnel was connected to a pump which in turn removed the floated solids that entered the skimmer system to waste.

PHASE III (DECEMBER 26, 1976 - MARCH 28, 1977)

The system was started up again on December 21 without sludge seeding in an attempt to develop a sludge entirely free of filamentous organisms. However, as a result of leakage across the dividing baffles in the return sludge well, cross seeding did occur between the oxygen system and the adjacent air basin.

Data acquisition, largely suspended during the previous period, was resumed on December 26. On December 30, two additional downdraft pumps became available and were installed in the basin to improve float re-entrainment. Attempts at float removal using the float skimmer had proved ineffective, and the device was removed from service. Poor effluent quality and continued high SVI's from the startup of Phase III through January 19 resulted in another system shutdown on January 20. The basin was emptied and re-seeded on January 21 with the objective of leaving the float solids in place, with no attempts to re-entrain or skim. Although effluent quality was acceptable for the remainder of January, filamentous counts again were high and influent flow was limited to rates approximating 22,700 m^3/day (6 mgd).

On January 10, a consultant was employed by the FMC Corporation to investigate the filamentous conditions existing in the oxygen activated sludge; his reports are presented in Appendix B. While undertaking studies to determine the types of filamentous organisms present in the sludge, the consultant indicated that the organisms were common to both the open tank oxygen and air activated sludge systems operating at Metro and that they may have been introduced into the systems by the influent wastewater feeding the North Complex. He further indicated that the character of the poorly settling sludge was that of floc built upon a filament backbone, and that such character resulted from a combination of filaments in the wastewater and the generally weak, thin nature of the waste. With a lack of substance in the influent on which to build a compact floc, the floc was instead growing on the available filament structure. The filament thought to be responsible for the poor sludge settling characteristics was believed to be an acid-producing relative of Sphaerotilus, a sheathed organism not previously described.

Following a recommendation of the consultant, a comparison of the settling characteristics of the open tank oxygen and air activated sludge systems was undertaken to determine if problems existed in the air system similar to those observed in the oxygen system. The closed tank oxygen system, treating different wastewater in the Metro South Complex, was included in this study for comparison (see Section 8, Comparative Settleabilities).

Since all efforts directed towards removing or re-entraining float material had proved largely unsuccessful, the system was drained again on January 31 to allow for the construction and installation of an overflow weir system in the mixed liquor basin to facilitate float removal (Figure 11). Float accumulation in the basin had been primarily a result of a submerged outlet from the aeration basin which did not allow float solids to exit from the system. It was expected that the surface outlet provided by the overflow weir would eliminate the float accumulation. With a fixed overflow weir, it was necessary to maintain a constant liquid level in the aeration basin not subject to diurnal level fluctuations in the influent channel. To achieve this, the normal sewage inlet to the mixed liquor basin was sealed and a system of air-lift pumps, easily regulated for either steady state or diurnal flow, was installed at the head end of the basin. The pump system consisted of three units, each capable of delivering approximately 189 l/sec (3000 gpm).

Installation of the overflow weir and air-lift pumps was completed on February 23, with the system restarted on February 24. Data acquisition began on March 8. Following installation of the weir, float accumulation on the mixed liquor surface was markedly reduced, but not eliminated. Despite the float reduction, no improvements were observed in the filamentous character of the sludge or in the sludge settleability.

From March 8 until the end of Phase III on March 28, effluent quality, at a flow rate of 23,500 m^3/day (6.2 mgd), was generally good despite gradually increasing SVI values for the mixed liquor. Sludge return rates, held at 88 percent (R/Q) for this period, may have aided in improving effluent quality from the previous operating period by removing sludge rapidly from the clarifier.

Over the course of Phase III, effluent quality averaged 57 mg/l SS and 33 mg/l BOD at an average F/M loading of 0.64 kg BOD/day/kg MLVSS. Clarifier overflow rates averaged 21.3 m^3/day/m^2 (522 gpd/ft^2).

PHASE IV (MARCH 29 - MAY 4, 1977)

At a project coordination meeting on March 24, it was noted that two objectives of the project had not been met due to a preoccupation with sludge quality and attempts to improve it. First, the system had not been operated in any diurnal flow pattern; second, the system had not been tested at elevated flow rates. It had been clear for some time that, with poor sludge settleability, the system was clarifier limited. With excess clarifier capacity recently made available by Metro, a decision was made to use two clarifiers for subsequent operations. On March 29, clarifier No. 11 was removed from the system and the mixed liquor was diverted to clarifiers No. 7 and 9 (Figure 2). The flow rate was gradually increased to 37,800 m^3/day (10 mgd) and regulated to a diurnal pattern approximating that normally seen at Metro (Figure 12).

Effluent quality, at an average flow of 37,100 m^3/day (9.8 mgd) for the phase, remained relatively poor, with sludge bulking occurring rather consistently during peak flow periods. This bulking, at peak flow rates approximating 49,200 m^3/day (13 mgd), was directly attributable to continuing problems with sludge quality. However, it did appear that sludge settleability was beginning to improve to some extent and it was decided to "wait out" the process in hopes of further improvement.

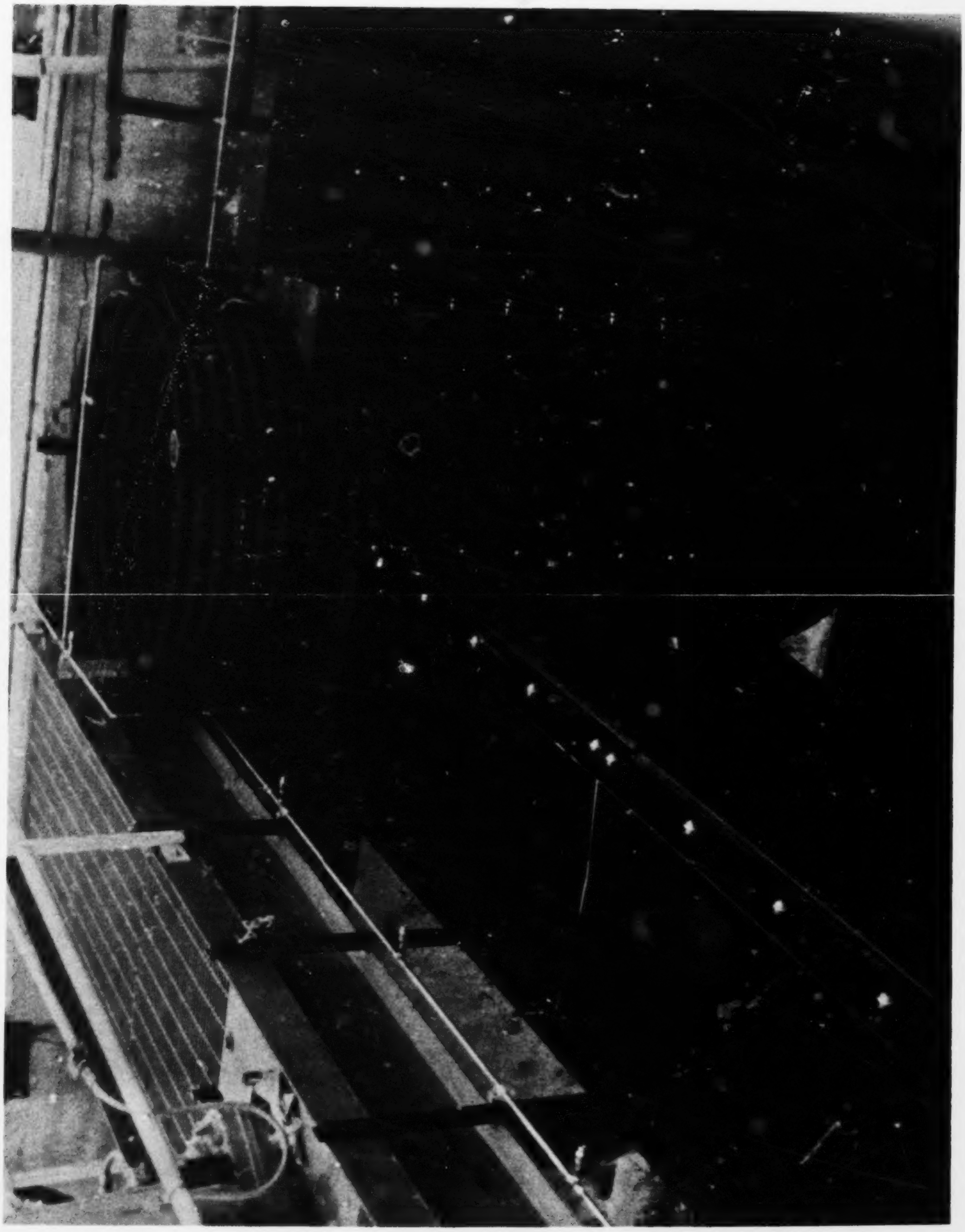

Figure 11. Mixed liquor basin overflow weir.

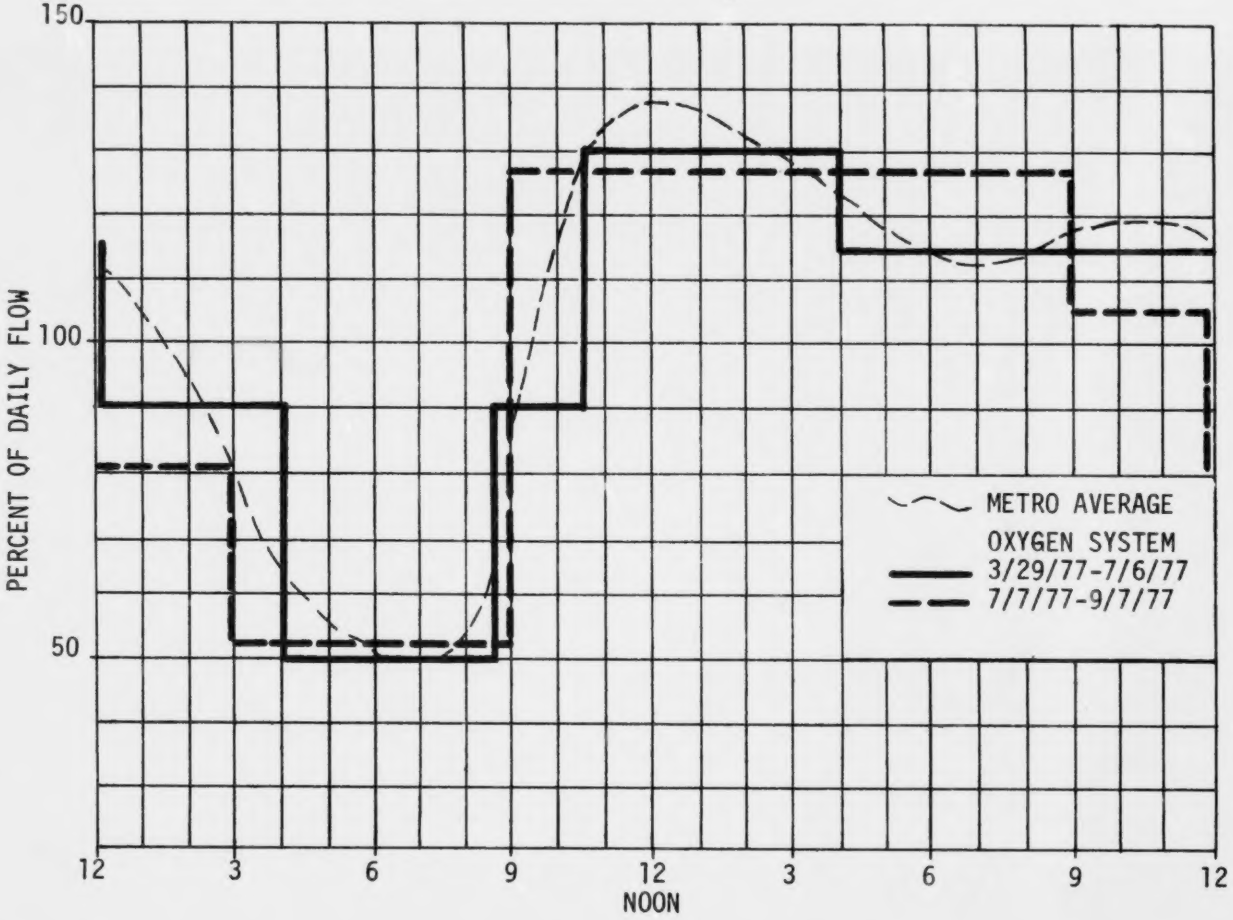

Figure 12. Diurnal flow patterns.

A problem occurring for the first time during Phase IV was the appearance of algae in the final effluent. This algae, which could be seen growing in the effluent launders and on the weirs of the clarifiers, undoubtedly contributed to the reported values for effluent SS and BOD. On nine of the 37 operating days in this phase, the laboratory reported the presence of varying amounts of algae in the final effluent composite samples analyzed. The cause of the algal growth was not determined, but the growth was not unique to the open tank oxygenation system. A similar proliferation had occurred at varying times in Metro's closed tank oxygenation system, though not to any appreciable extent in the air system.

Overall performance during Phase IV demonstrated an average effluent quality of 41 mg/l SS and 31 mg/l BOD. The F/M loading rate, reflecting increased flow, rose to 1.14 kg BOD/day/kg MLVSS. Clarifier overflow rates, with the addition of a second clarifier to the system, decreased to an average of 16.5 m^3/day/m^2 (406 gpd/ft^2).

PHASE V (MAY 5 - JUNE 6, 1977)

Maintaining the diurnal flow pattern established during Phase IV, influent flow was increased to an average 45,800 m^3/day (12.1 mgd) during Phase V. It can be seen in Table 3 that mixed liquor unstirred SVI values decreased significantly, averaging 150 ml/g for the phase. Final effluent quality was generally superior to the 30 mg/l SS and 23 mg/l BOD reported for the phase, as the averages contain several anomalous data points. Algae was noted, though less frequently than in the previous phase, in three of the 33 final effluent composite samples collected. In addition, 2 day's data, shown in Appendix A, deserve special mention. The unusually high values of 148 mg/l SS and 49 mg/l BOD for the effluent sample of May 11 resulted from an exceptionally high influent SS loading of 257 mg/l*. Although later in the demonstration, the system exhibited the ability to handle such loadings easily without adverse effect, at this time sludge settleability had not improved sufficiently to prevent bulking with the high influx of solids. The effluent sample of May 28, with values of 83 mg/l SS and 62 mg/l BOD, contained clumps of a greyish slime which, upon microscopic examination, consisted of colonies of _Vorticella_ sp., a growth of ciliated protozoans which had been observed growing along with the algae in the clarifiers. Elimination of these two data points from the phase averages would result in an effluent quality of 24 mg/l SS and 20 mg/l BOD, values more representative of the performance of the system than those shown in Table 2.

Although the algal growth in the clarifiers was diminishing during this phase, the continued presence of algae in some of the effluent samples collected prompted a decision to institute, on May 30, a manual sampling program to replace the automatic sampler used up to this time. It was theorized that the automatic sampler influent line might be located so as to provide a sample containing debris not visibly apparent in the effluent leaving the clarifier. Comparison data taken over several days revealed the consistent presence of algae and Vorticella slime in the automatically collected samples and only minimal amounts in the manual samples. Following institution of the manual sampling program, algal contamination of final effluent samples ceased for all practical purposes.

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* The elevated loading level was traced to the air-lift pumping arrangement used to supply influent to the oxygen system basin; at low flow in the influent channel, the pumps would actually draw mixed liquor solids from adjacent air system basins to make up for the flow deficit.

Overall during Phase V, the effluent quality mentioned above was achieved at a system F/M loading average of 1.10 kg BOD/day/kg MLVSS, with clarifier overflow rates averaging 20.4 m^3/day/m^2 (501 gpm/ft^2).

PHASE VI (JUNE 7 - AUGUST 4, 1977)

This phase was divided into the two operating periods shown in the data tables to produce approximately 1-mo operating periods. There were no significant differences in operating parameters between the two periods other than a decrease in F/M loadings resulting from a decline in influent wastewater BOD during the second period. The flow during this phase was increased to an average of 53,000 m^3/day (14.0 mgd). Although a diurnal flow pattern was maintained, the nature of the pattern was changed on July 7 (Figure 12) due to constraints in operating the Metro air system. Unstirred SVI levels, as a result of a diminishing filamentous population (Figures 9, 13), decreased to an average of 107 ml/g. As a result, the system responded with the finest effluent quality of the demonstration, averaging 16 mg/l SS and 12 mg/l BOD. F/M loadings for the phase averaged 0.85 kg BOD/day/kg MLVSS, with clarifier overflow rates averaging 23.7 m^3/day/m^2 (581 gpd/ft^2).

Although the system showed no signs of being anywhere near its failure point at 53,000 m^3/day (14.0 mgd), a practical hydraulic limit was reached during peak-flow (68,000 m^3/day, 18 mgd ±) periods. The installed overflow weir so elevated the liquid level in the mixed liquor basin that the support bridges for the diffuser drives became partially submerged.

PHASE VII (AUGUST 5 - SEPTEMBER 7, 1977)

The hydraulic limitations discussed above, coupled with the fact that previous operation at 45,800 m^3/day (12.1 mgd) during Phase V had yielded less than desired results, prompted a decision to return to a nominal 45,400 m^3/day (12-mgd) diurnal operation in order to acquire additional performance data at this flow rate.

Unstirred SVI values continued to decrease and averaged under 100 ml/g for the phase. The influent flow rate averaged 46,600 m^3/day (12.3 mgd), resulting in an F/M loading of 0.75 kg BOD/day/kg MLVSS and a clarifier overflow rate of 20.8 m^3/day/m^2 (511 gpd/ft^2). Effluent quality remained excellent, averaging 17 mg/l SS and 13 mg/l BOD.

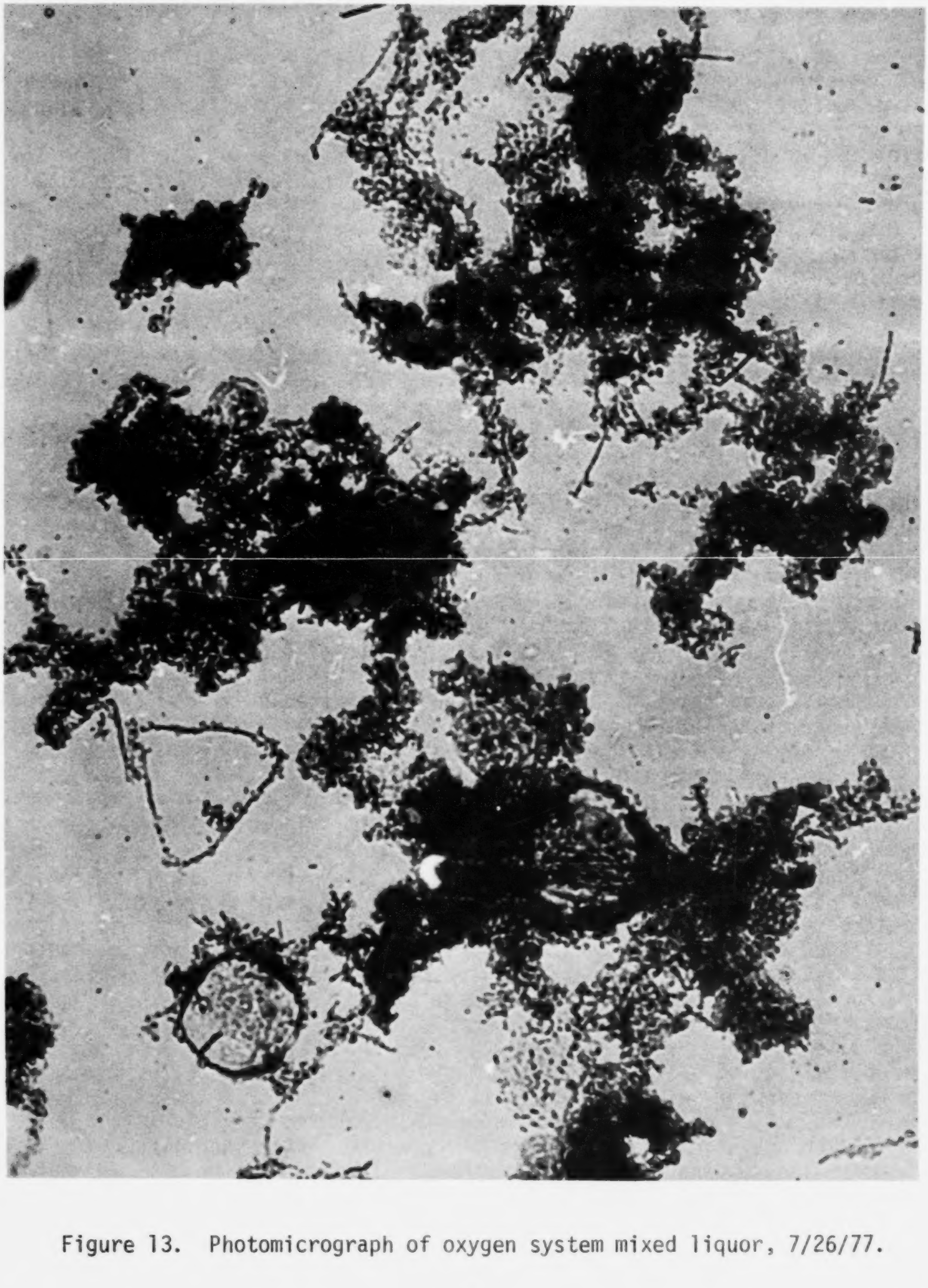

Figure 13. Photomicrograph of oxygen system mixed liquor, 7/26/77.

OPERATION SUMMARY

An overview of the seven operating phases detailed above shows that the initial performance of the system was satisfactory; a proliferation of filamentous organisms then led to a marked deterioration of the system performance extending over a period of several months, with subsequent recovery of the system and excellent performance during the latter phases of operation. Attempts at determining the causes of the filamentous proliferation met with no success. Investigations of float involvement, the influence of both high and low D.O. levels in the mixed liquor, and the effect of high F/M loadings did not provide an answer. Filamentous conditions at both high and low mixed liquor temperatures appeared to rule out a solely temperature related phenomenon (10).

Also unexplained is the disappearance of the filamentous organisms from the system. Other than increasing the flow rate through the system, with resultant increases in system loadings, no operational changes were made which could explain the improvement in sludge quality and attempts to tie the improvement to the flow or loading changes would be purely conjectural.

There is a possibility that the filamentous appearance and disappearance may have been related to changes in influent wastewater characteristics (see Section 8, Comparative Settleabilities). This, however, does not explain the rapid growth of the culture in the oxygen system as compared to the diffused air system during several of the operating phases. With the two systems operating at different F/M loadings, detention times, etc., any of a number of factors may have been responsible for this disparity.

A hypothesis submitted by the system supplier to account for the filamentous growth experienced in the oxygen system is as follows: At the time of initial startup of the system, the influent wastewater may have had essentially nonfilamentous characteristics. As a result, the system developed a good settling sludge. Float accumulation over a period of approximately 90 days contributed to a sudden increase in and continuation of filamentous growth during July 1976, resulting in a system shutdown in August 1976. Subsequent attempts to restart during the fall of 1976 and the winter of 1976-77 occurred when the influent wastewater was of a filamentous nature, explaining the rapid growth of filamentous organisms after these startups. In each case, operation was discontinued after a short period, with insufficient time allowed for the system to stabilize. Following installation of the overflow weir in February 1977, the system was restarted, again with an influent wastewater having filamentous characteristics. Rapid filamentous growth occurred for a period of approximately 6 weeks following startup, followed by a sudden reduction in filamentous counts. This significant improvement was caused by: 1) the overflow weir preventing excessive accumulation of floated solids on the mixed liquor surface, 2) a change in basic influent wastewater characteristics from filamentous to nonfilamentous, 3) a change in the mixed liquor temperature, or 4) a combination of any of these three factors. Both 1) and 2) were accompanied by operation for an adequate time to permit system acclimation. Continued operation resulted in the development of a sludge with better settling characteristics than those of the parallel operating air system.

In any case, the last 3½ mo of operation with the FMC O_2 system comprised a period of excellent performance at relatively high F/M loadings, at mixed liquor temperatures comparable to those experienced in previous operating periods yielding poor performance, at mixed liquor D.O. levels similar to those maintained earlier, and with no basic alterations in the philosophy of operation of the system. With two clarifiers in use during this time, overflow rates were limited to those mentioned under the various operating phases. However, sludge settleability and blanket levels were such that higher overflow rates might well have been achieved.

SECTION 8

COMPARATIVE SETTLEABILITIES

Beginning in April 1977 and continuing until the end of the project, a comparison of mixed liquor SVI values was made on samples from both the open (FMC O_2) and closed (UNOX) tank oxygen systems and the diffused air system. The purpose of this study was to determine if the sludge settling difficulties experienced with the open tank oxygen system were unique to that system, or were common to either or both of the other operating systems at the plant.

For each settling test, stirred SVI's were run on mixed liquor samples as collected and at 25 percent and 50 percent dilutions (made with final effluent from the system being tested) so that the data could be plotted to yield SVI values for each system at equivalent solids concentrations. The data, plotted as SVI adjusted to a mixed liquor suspended solids concentration of 2000 mg/l, are shown in Figure 14.

It is important to note that although the air and FMC O_2 systems operating in Metro's North Complex were at all times treating the same influent wastewater, the influent to the UNOX system in the South Complex was a separate wastewater stream. On several occasions during the course of the project, influent sources were switched so that the three systems were treating different wastewaters at various times. Wastewater "A" in Table 4 was the primary effluent from the Denver North Side Sewage Treatment Plant, a waste from the City of Denver proper containing packing house and other industrial wastes, the domestic waste from the city, and supernatant from the Denver North Side anaerobic digesters. Wastewater "B" was a somewhat more domestic waste collected from suburban Denver communities and given primary treatment at Metro's primary facility; also included in this stream were the Metro in-plant wastes. Table 4 depicts the pattern of differing wastewater distribution to the three treatment systems during the project.

Observations made earlier in the demonstration indicated that the FMC O_2 system sludge settleability had been more severely affected by filamentous organisms than that of the air system. However, it is apparent in Figure 14 that for the duration of the comparative test period the settleabilities of the two systems tracked closely with one another. The UNOX system, treating different wastewater, exhibited a markedly different trend. These observations suggest the possibility that influent wastewater characteristics may have played a significant role in determining sludge quality. This hypothesis is further supported by the fact that each time the influent sources to the North and South Complexes were switched, on June 25 and again on August 23, 1977, the systems newly receiving the Denver North Side wastewater appeared

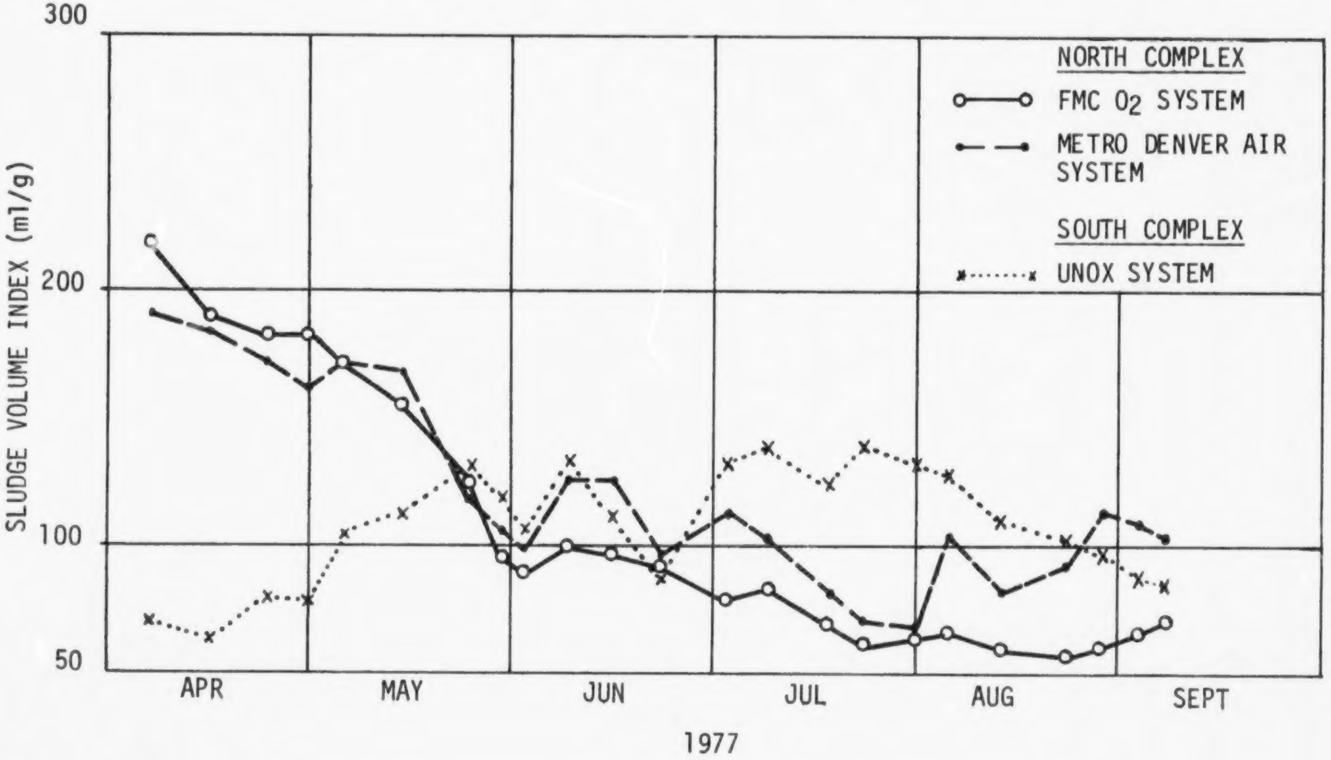

Figure 14. Comparison of SVI values (adjusted to 2000 mg/l MLSS) for oxygen and air systems.

to be adversely affected. While not sufficient to establish a relationship between influent wastewater and sludge quality, these observations do indicate that such a relationship may have existed.

TABLE 4. INFLUENT WASTEWATER DISTRIBUTION

Period	System	Wastewater*
6/1/76 - 11/14/76	Air and FMC O_2 UNOX	A (62%) + B (38%) Off Line
11/15/76 - 6/24/77	Air and FMC O_2 UNOX	A (100%) B (100%)
6/25/77 - 8/22/77	Air and FMC O_2 UNOX	B (100%) A (100%)
8/23/77 - 9/7/77	Air and FMC O_2 UNOX	A (100%) B (63%) + A (37%)

* Wastewater "A" = Denver North Side primary effluent and digester supernatant.

Wastewater "B" = Metro primary effluent and in-plant wastes.

SECTION 9

OXYGEN TRANSFER EFFICIENCY

The method employed to evaluate the efficiency of oxygen transfer from specific diffusers into the mixed liquor required the capture of all gases leaving a representative area of free liquid surface and the determination of the oxygen fraction of those gases. The total off-gas oxygen thus measured, extrapolated from the test area to the total area of influence for the monitored diffuser, was compared to the total amount of oxygen flow to the diffuser to yield the oxygen transfer efficiency. As the off-gas capture was made over a surface area representing only a part of the area of influence of the diffuser being tested, it was necessary to establish that different test areas within an influence area would yield approximately equivalent values for the transfer efficiency.

Due to the impossibility of isolating the diffuser under test from adjacent diffusers in the basin, oxygen flow was set during each test so that the target diffuser and all adjacent diffusers were receiving equivalent oxygen flow rates. The possibility of transient oxygen demand conditions in the basin influencing the measurements was reduced by conducting each test over a period of several hours, monitoring for steady state conditions and using the data obtained during such periods.

OFF-GAS TEST EQUIPMENT

The equipment used for off-gas collection and analysis is shown schematically in Figure 15. A floating dome captured the gas leaving a 3.7-m^2 (40-ft^2) area of the basin surface. A 17.8-cm (7-in.) diameter water filled tube was attached around the periphery of the dome to provide stability and prevent tilting of the dome under conditions of increasing off-gas volume.

The captured off-gas was transferred from the dome through a flexible hose to an oxygen gas analyzer (Biomarine Industries, Model OAR 602) and then to a wet test meter (Precision Scientific Company, Model 63126) before being vented to atmosphere. Revolutions of the wet test meter were detected and counted by means of a proximity switch (Electro-Corporation, Versa Switch Model 50) which provided accurate accounting of off-gas displacement through the meter. A strip chart event marker was used with the wet test meter to measure the time per revolution of the meter. These recorded data, together with the oxygen analyzer data, allowed for a precise determination of steady state conditions. The wet test meter was equipped with a mercury thermometer to allow for the conversion of measured gas volumes to volumes at standard temperature conditions.

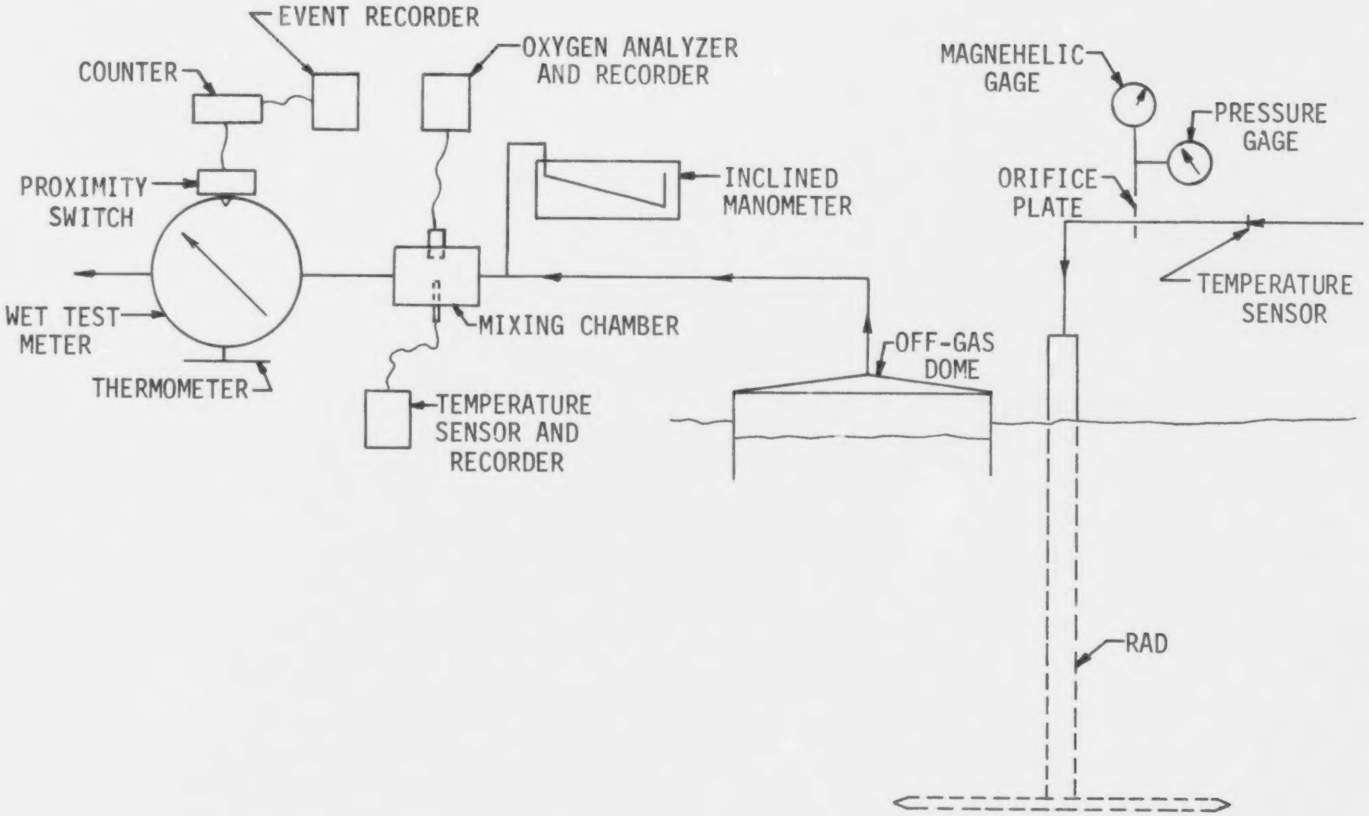

Figure 15. Schematic of off-gas test equipment.

A thermistor and strip chart recorder provided continuous temperature monitoring in the vicinity of the oxygen gas analyzer, and an inclined water manometer tapping the off-gas line from the dome allowed monitoring of the approximate gas pressure under the dome. Data from these sensors was used for test monitoring only, rather than for data evaluation.

For oxygen flow to the system, an orifice plate and needle valve located in the oxygen line to each diffuser allowed for adjustment and measurement of differential and upstream pressure. These parameters, combined with measurements of oxygen temperature, allowed for the accurate determination of oxygen flow.

Prior to the start of each test period, the Biomarine oxygen gas analyzer was calibrated in air pursuant to the manufacturer's instructions, and additional checks were made at intervals with a second instrument (Taylor Indusries, Model OA 250) to verify calibration of the Biomarine unit. Calibration of the wet test meter was performed prior to use by comparison with a rotameter (Fischer Porter, Tube No. FP-1/8-20-G-5/840).

DATA REPRESENTATION

Figure 16 shows the locations of the off-gas dome during the oxygen transfer test periods. RAD's 1 through 4 were not tested because of severe surface turbulence near the head end of the basin resulting from the surface discharge of influent wastewater into the basin. RAD's 9 and 11 were not tested because of visually apparent diffuser leaks.

Test results are shown in Figure 17, with oxygen transfer efficiency depicted as a function of oxygen flow rate to the diffusers under test. The actual data points shown represent the mean values of numerous determinations made over the course of each test period. The dashed boxes surrounding each data point give an indication, horizontally, of the degree of accuracy estimated for oxygen flow measurements and, vertically, of the standard deviation of the individual transfer efficiency measurements contributing to the mean.

Measured oxygen transfer efficiencies were consistently in excess of 96 percent at gas flow rates at or below design flow for the diffusers. Even at gas flows more than 25 percent higher than design, transfer efficiencies exceeded 92 percent with the exception of efficiencies measured downstream of RAD 7. This RAD was equipped with an experimental diffusion medium for evaluation purposes, a medium incapable of producing as fine an oxygen bubble as the other RAD's in the system.

The data from three of the test locations shown in Figure 16 are not shown in Figure 17. Low transfer efficiencies were found at the dome locations upstream of RAD 6, downstream of RAD 12, and upstream of RAD 13. The poor performance at RAD 6 was traced to leaks in RAD's 5 and 6, both repaired prior to acquiring data shown for the test downstream of RAD 6. After completion of the off-gas testing, RAD 12 was also found to be leaking, and this was believed responsible for the poor transfer efficiencies measured at both RAD's 12 and 13. The leaks were traced to a process problem in the manufacture of the diffuser tile assemblies, and this problem has since been corrected.

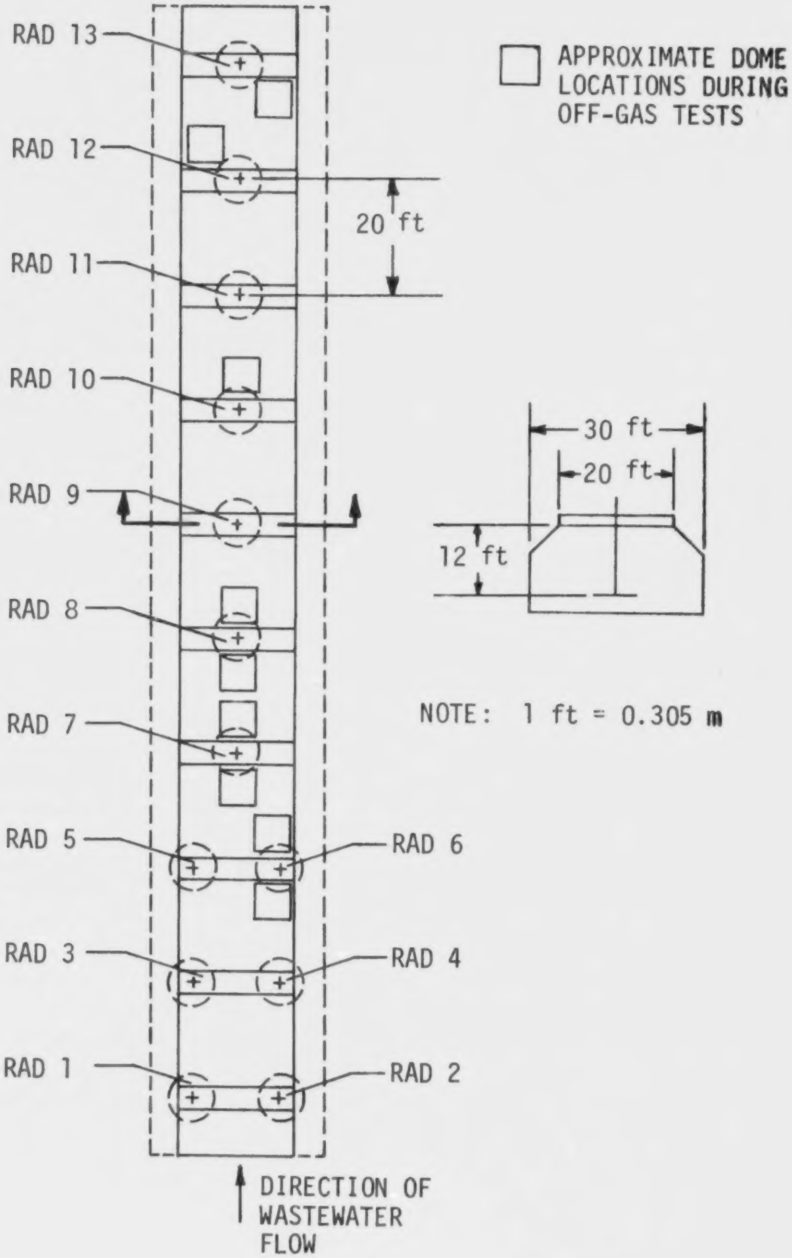

Figure 16. Off-gas dome locations.

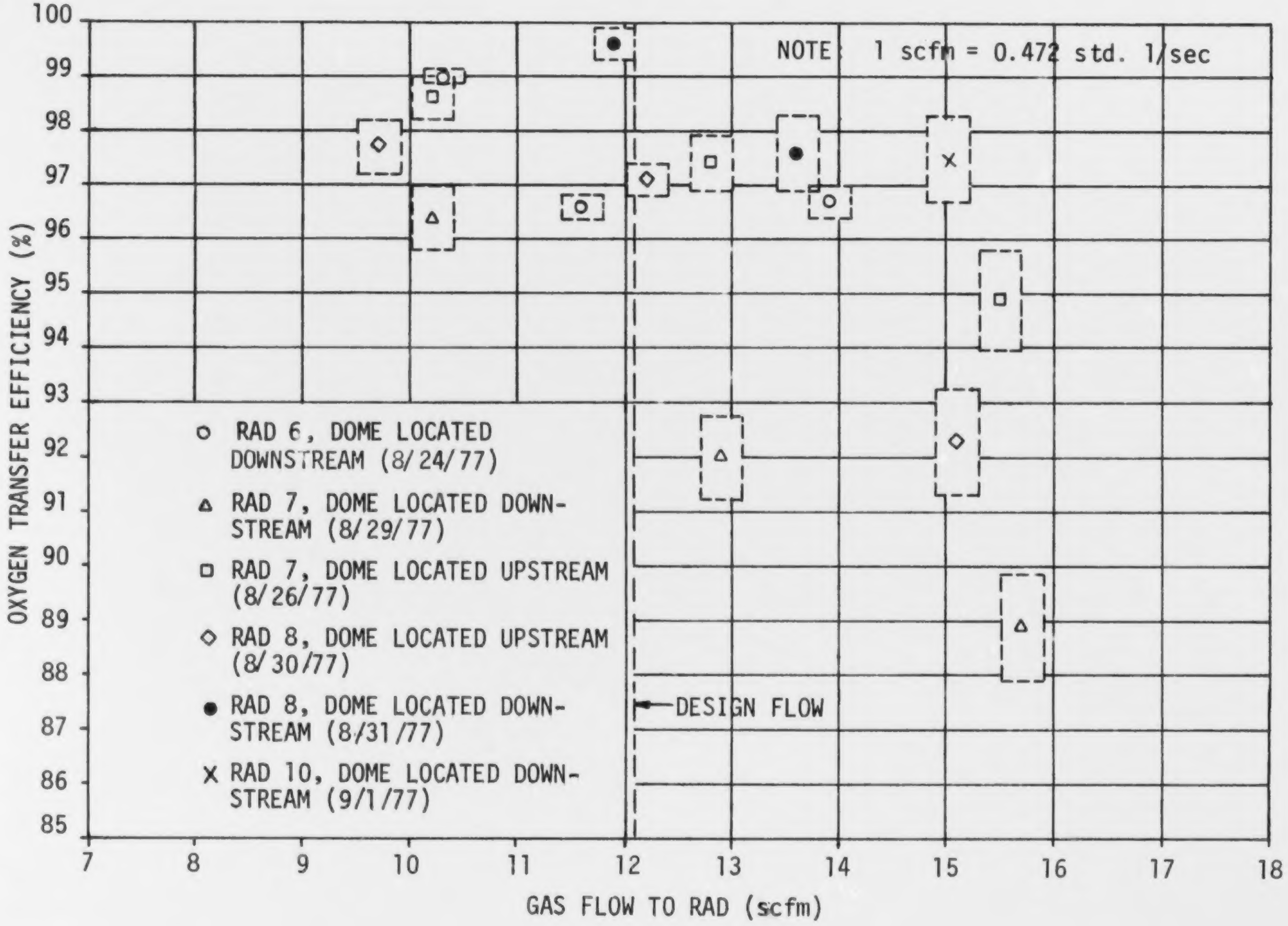

Figure 17. Oxygen transfer efficiency versus oxygen flow at various basin locations.

SECTION 10

SOLIDS PRODUCTION

Oxygen system solids accumulation, expressed as a function of both BOD removed (BOD_R) and BOD applied (BOD_A), is summarized in Table 5. BOD_A data have been presented along with the more conventional BOD_R relationship because the latter results in misleading interpretations under sludge bulking conditions, where effluent BOD does not reflect mixed liquor basin performance. Both gross and net solids accumulation values are presented, with the net figure discounting influent solids to give an approximation of solids accumulation resulting from BOD oxidation. The low sludge yields shown for the first two periods of Phase II can be attributed to the relatively long SRT of 9 to 10 days (based on total system inventory) maintained during these periods, as compared to a 3-to 6-day SRT for the balance of the demonstration.

Table 6 shows a comparison of solids accumulation data between the oxygen system and Metro's diffused air system. As seen in the gross solids accumulation figures, the air system exhibited an overall solids accumulation of 0.99 kg SS/kg BOD_R, as compared to 1.12 kg SS/kg BOD_R for the oxygen system, at comparable SRT's. Although these figures appear to indicate that sludge production in the air system was lower than in the oxygen system, they do not take into account differences in influent solids concentrations. The influent BOD concentrations were virtually identical for the two systems during the course of the demonstration, but the oxygen system influent SS concentration was significantly higher than that of the air system much of the time. Through the second operating period of Phase II, the concentration of SS in the influent to the oxygen system was equivalent to that of the air system. However, the startup of the South Complex treatment facility in November 1976 and the resultant flow reduction to the North Complex produced an uneven distribution of solids in the North Complex secondary influent channel. From the third operating period of Phase II through the remainder of the demonstration, the oxygen system influent averaged 29 percent higher in SS concentration than the air system influent. This is accounted for in the net solids accumulation figures in Table 6, which show virtually equivalent overall sludge production for the two systems.

TABLE 5. OXYGEN SYSTEM SOLIDS PRODUCTION

Phase	Period	Suspended Solids (lb/day)°				BOD (lb/day)°		Solids Accumulation			
								kg SS/kg BODR		kg SS/kg BODA	
		Influent	Effluent	Waste	Δ Inventory	Influent	Effluent	Gross*	Net+	Gross*	Net+
I	6/1/76 - 6/30/76	6,960	2,420	5,070	-230	9,970	1,530	0.86	0.04	0.73	0.03
	7/1/76 - 7/31/76	6,590	2,080	5,580	+ 30	9,150	1,780	1.04	0.15	0.84	0.12
	8/1/76 - 8/31/76	6,260	4,020	4,570	-210	7,880	2,430	1.54	0.39	1.06	0.27
II	9/1/76 - 9/28/76	4,190	1,540	2,230	-410	6,070	1,060	0.67	-0.17	0.55	-0.14
	10/7/76 - 10/31/76	4,460	670	2,440	+740	6,200	420	0.67	-0.11	0.62	-0.10
	11/1/76 - 11/21/76	4,690	2,640	3,130	-250	6,290	960	1.04	0.16	0.88	0.13
III	12/26/76 - 1/31/77	5,790	4,380	2,920	+510	8,490	2,330	1.27	0.33	0.92	0.24
	3/8/77 - 3/28/77	5,550	970	6,090	- 70	8,690	850	0.89	0.18	0.80	0.17
IV	3/29/77 - 5/4/77	8,620	3,320	9,880	+100	12,960	2,510	1.27	0.45	1.03	0.36
V	5/5/77 - 6/6/77	10,590	2,990	11,970	+ 30	14,960	2,330	1.19	0.35	1.00	0.29
VI	6/7/77 - 7/4/77	12,500	1,690	14,560	+250	16,080	1,480	1.13	0.27	1.03	0.25
	7/5/77 - 8/4/77	11,900	1,930	13,490	-400	12,660	1,450	1.34	0.28	1.19	0.25
VII	8/5/77 - 9/7/77	12,510	1,690	13,730	-390	13,460	1,290	1.24	0.21	1.12	0.19

° lb/day = 0.454 kg/day

* Gross = (Effluent + Waste + Δ Inventory) SS/BOD

+ Net = (Effluent + Waste + Δ Inventory - Influent) SS/BOD

TABLE 6. SOLIDS PRODUCTION - AIR VERSUS OXYGEN

		Oxygen System			Air System		
		kg SS/kg BOD_R			kg SS/kg BOD_R		
Phase	Period	Gross*	Net+	SRT (days)•	Gross*	Net+	SRT (days)•
I	6/1/76 - 6/30/76	0.86	0.04	4.8	1.05	0.21	4.3
	7/1/76 - 7/31/76	1.04	0.15	5.4	1.09	0.14	3.9
	8/1/76 - 8/31/76	1.54	0.39	4.3	1.15	0.12	3.7
II	9/1/76 - 9/28/76	0.67	-0.17	9.8	1.01	0.09	4.0
	10/7/76 - 10/31/76	0.67	-0.11	9.6	1.02	0.18	4.2
	11/1/76 - 11/21/76	1.04	0.16	5.7	1.02	0.28	5.1
III	12/26/76 - 1/31/77	1.27	0.33	4.7	0.79	0.20	6.6
	3/8/77 - 3/28/77	0.89	0.18	4.9	0.92	0.31	6.2
IV	3/29/77 - 5/4/77	1.27	0.45	3.8	1.03	0.42	5.9
V	5/5/77 - 6/6/77	1.19	0.35	3.5	0.93	0.33	4.8
VI	6/7/77 - 7/4/77	1.13	0.27	3.9	0.92	0.27	5.4
	7/5/77 - 8/4/77	1.34	0.28	4.0	1.08	0.23	3.7
VII	8/5/77 - 9/7/77	1.24	0.21	3.4	0.66	-0.04	6.2
	Overall	1.12	0.22	5.1	0.99	0.20	4.9

* Gross = (Effluent + Waste + Δ Inventory) SS/BOD_R

+ Net = (Effluent + Waste + Δ Inventory - Influent) SS/BOD_R

• Based on total system inventory

SECTION 11

OXYGEN CONSUMPTION

Oxygen consumption as a function of several parameters is presented in Table 7. This discussion focuses on the relationship between oxygen supplied and BOD_R, but is generally applicable to the other relationships presented as well. The underlined data, with a mass weighted average of 1.23 kg O_2/kg BOD_R, is considered representative of system performance under normal operating conditions. The relatively high oxygen consumption experienced in the second period of Phase I was attributed to malfunctions of the dissolved oxygen sensing system which caused excess oxygen to be supplied to the basin. Poor BOD removal resulting from sludge bulking produced the high consumption figures shown for the third operating period of Phase I and the first operating period of Phase III. Evidence of this can be seen in the disparity between BOD_A and BOD_R figures for these two periods. Phase II was characterized by both high SRT's and long mixed liquor basin detention times, a combination favoring endogenous respiration and requiring additional oxygen. Leaking diffusers (see Section 9, Oxygen Transfer Efficiency) were responsible for the anomalous oxygen consumption values shown for the last two operating periods of the demonstration.

TABLE 7. OXYGEN CONSUMPTION

Phase	Period	Oxygen Supplied (lb/day)•	Oxygen Supply Rate $\frac{\text{kg O2}}{\text{kg BOD}_A}$	$\frac{\text{kg O2}}{\text{kg BOD}_R}$	$\frac{\text{kg O2}}{\text{kg TOC}_R}$	$\frac{\text{kg O2}}{\text{kg COD}_R}$*	$\frac{\text{kg O2}}{\text{kg COD destroyed}}$+
I	6/1/76 - 6/30/76	11,363	1.14	1.35	2.59	0.79	1.42
	7/1/76 - 7/31/76	12,307	1.35	1.67	2.70	0.83	1.57
	8/1/76 - 8/31/76	10,264	1.30	1.88	3.00	0.91	1.84
II	9/1/76 - 9/28/76	8,819	1.45	1.76	2.88	0.89	1.25
	10/7/76 - 10/31/76	8,866	1.43	1.53	2.48	0.77	1.04
	11/1/76 - 11/21/76	8,444	1.34	1.58	2.62	0.81	1.29
III	12/26/76 - 1/31/77	9,012	1.06	1.46	2.39	0.73	1.04
	3/8/77 - 3/28/77	9,363	1.08	1.19	1.94	0.60	1.15
IV	3/29/77 - 5/4/77	11,224	0.87	1.07	1.72	0.53	1.27
V	5/5/77 - 6/6/77	15,593	1.04	1.23	1.91	0.59	1.36
VI	6/7/77 - 7/4/77	19,001	1.18	1.30	2.05	0.64	1.69
	7/5/77 - 8/4/77	20,474	1.62	1.83	2.83	0.88	2.89
VII	8/5/77 - 9/7/77	20,366	1.51	1.67	2.50	0.78	2.09

• 1 lb/day = 0.454 kg/day

* COD values are calculated quantities based on TOC. Influent COD = 3.17 (± 0.27) TOC and effluent COD = 3.00 (± 0.44) TOC factors are based upon 25 and 26 determinations, respectively, over the course of the project.

+ COD destroyed = influent COD - (effluent COD + waste COD). COD values for influent and effluent calculated as above; COD for the waste sludge = 1.50 (± 0.10) VSS, based upon 15 determinations made during the project.

SECTION 12

POWER REQUIREMENTS

Power requirements for operation of the FMC O_2 system are shown in Table 8, with the air system data, where available, shown for comparison. It should be emphasized that actual oxygen generation power requirements for the oxygen system were not available, as all of the oxygen used was purchased from an outside vendor. The oxygen generation power requirement data shown in the table was derived from power requirements experienced during March 1978 in the operation of the cryogenic oxygen plant serving Metro's South Complex*. Power required for oxygen compression is shown in the table for installations in which the cryogenic plant output pressure is insufficient for the requirements of the open tank oxygen dissolution system. A cryogenic plant capable of output pressures of 21,100 to 24,600 kgf/m^2 (30 to 35 psig) would eliminate this power requirement.

The overall power requirement differences among the various operating periods resulted from the fact that the power required for oxygen dissolution was a constant, independent of flow rate and organic loading. During Phases II and III, with average flow rates at 49 percent and BOD loadings at 46 percent of design, power requirements (flow or mass weighted, as appropriate) averaged 151 kWh/1000 m^3 (571 kWh/mil gal) treated and 1.28 kWh/kg BOD_R (0.58 kWh/lb BOD_R). During Phases I and IV, where flow rates averaged 75 percent and BOD loadings 66 percent of design, power requirements averaged only 111 kWh/1000 m^3 (422 kWh/mil gal) treated and 1.13 kWh/kg BOD_R (0.51 kWh/lb BOD_R). In Phases V, VI, and VII, with flow rates averaging 105 percent and BOD loadings 92 percent of design, the power required decreased to 109 kWh/1000 m^3 (411 kWh/mil gal) treated and 0.93 kWh/kg BOD_R (0.42 kWh/lb BOD_R). These latter figures would have been reduced even further, were it not for diffuser leaks and resultant excess oxygen consumption (see Section 9, Oxygen Transfer Efficiency).

A comparison of FMC O_2 system versus air system power requirements, for those periods where the air system data were available, shows a significant power savings in favor of the oxygen system. Overall averages for the air

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* During March 1978, the cryogenic plant produced an average 35.4 metric tons O_2/day (39.0 tons/day) at a power requirement of 392 kWh/metric ton (356 kWh/ton). This figure is a conservative estimate of the power required for oxygen generation, as it represents the highest value attained for cryogenic plant operation in the first 4 mo of 1978.

TABLE 8. SYSTEM POWER REQUIREMENTS

		Oxygen System						Air System	
		kwh/day for Oxygen							
Phase	Period	Dissolution*	Compression+	Generation	$\left(\frac{kWh}{mil\ gal}\right)^{**}$	$\left(\frac{kWh}{lb\ BOD_R}\right)^{++}$	$\left(\frac{kWh}{lb\ O_2\ supplied}\right)^{++}$	$\left(\frac{kWh}{mil\ gal}\right)^{**}$	$\left(\frac{kWh}{lb\ BOD_R}\right)^{++}$
I	6/1/76 - 6/30/76	1,791	123	2,023	413	0.47	0.35	-	-
	7/1/76 - 7/31/76	1,791	133	2,191	435	0.56	0.33	-	-
	8/1/76 - 8/31/76	1,791	111	1,827	454	0.68	0.36	-	-
II	9/1/76 - 9/28/76	1,791	95	1,570	568	0.69	0.39	-	-
	10/7/76 - 10/31/76	1,791	96	1,578	602	0.60	0.39	-	-
	11/1/76 - 11/21/76	1,791	91	1,503	575	0.64	0.40	-	-
III	12/26/76 - 1/31/77	1,791	97	1,604	550	0.57	0.39	626	0.56
	3/8/77 - 3/28/77	1,791	101	1,667	574	0.45	0.38	709	0.62
IV	3/29/77 - 5/4/77	1,791	121	1,998	400	0.37	0.35	769	0.71
V	5/5/77 - 6/6/77	1,791	168	2,776	393	0.37	0.30	785	0.77
VI	6/7/77 - 7/4/77	1,791	205	3,382	395	0.37	0.28	743	0.83
	7/5/77 - 8/4/77	1,791	221	3,644	396	0.50	0.28	653	0.71
VII	8/5/77 - 9/7/77	1,791	220	3,625	458	0.46	0.28	725	0.75

* Actual RAD drive power requirements as measured on October 7, 1976.

+ kWh required to compress cryogenic plant output to 30-35 psig. 21.6 kWh/ton** O_2 compiled from Englewood-Littleton (Colorado) Treatment Plant performance tests.

** 1 kWh/mil gal = 0.264 kWh/1000 m^3

++ 1 kWh/lb = 2.21 kWh/kg

** 1 kWh/ton = 1.10 kWh/metric ton

system were 189 kWh/1000 m^3 (716 kWh/mil gal) treated and 1.52 kWh/kg BOD_R (0.69 kWh/lb BOD_R), while the corresponding averages for the FMC O_2 system were 114 kWh/1000 m^3 (431 kWh/mil gal) treated and 0.95 kWh/kg BOD_R (0.43 kWh /lb BOD_R). Based on the air system power requirement, these figures represent a 40 percent reduction based on flow and a 38 percent reduction based on BOD_R for the oxygen system.

SECTION 13

SUPPLEMENTAL TESTING

NITROGEN FORMS, ALKALINITY, AND pH

Nitrogen forms, alkalinity, and pH data are presented in Table 9. These data were collected mainly for the purpose of monitoring any nitrification that might occur during the demonstration. As the data indicate, nitrification did not occur to any measurable extent except during July and August of the first operating phase, when effluent nitrate nitrogen levels averaged 1 to 2 mg/l. Alkalinity comparisons between the oxygen system and Metro's non-nitrifying air system revealed no significant variations. The pH reduction from influent to effluent of the oxygen system over the course of the project resulted from CO_2 production as a function of BOD oxidation, rather than from any reduction in the system alkalinity.

SOLUBLE BOD

Soluble BOD determinations on the oxygen system were run in conjunction with total BOD analyses on both influent and effluent samples to monitor mixed liquor performance independent of clarification. As seen in Figure 18, total and soluble BOD values for the influent wastewater tracked closely over the entire course of the demonstration, while effluent total BOD showed significant fluctuations only minimally reflected in the soluble BOD. The high effluent total BOD values shown were the result of poor clarification, rather than poor mixed liquor basin performance, and the overall average of 4 mg/l soluble BOD in the effluent indicates efficient biological treatment.

SUSPENDED SOLIDS PROFILE

A suspended solids profile of the mixed liquor basin was run on July 13, 1976, to verify that the mixing provided by the RAD's was sufficient to maintain a uniform concentration of suspended solids at varying depths of the basin. The data are presented in Figure 19. With the exception of location "A", the suspended solids variation at any depth for a particular location did not exceed 7 percent of the mean value for samples taken at that location. Location "A" was situated directly across the basin from the return sludge inlet, explaining the disparity in the measured solids levels at that location.

DISSOLVED OXYGEN PROFILE

A comprehensive D.O. profile of the mixed liquor basin was run on December 15,

TABLE 9. NITROGEN FORMS, ALKALINITY, AND pH

		Nitrogen Forms (Oxygen System)						Oxygen System pH*		Alkalinity (mg/l as $CaCO_3$)				
		TKN (mg/l)		NH_4^+-N (mg/l)		NO_2^--N + NO_3^--N (mg/l)					Oxygen System		Air System	
Phase	Period	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Head	Tail	Head	Tail
I	6/1/76 - 6/30/76	27.3	22.8	17.7	16.9	0.05	0.04	-	-	241	253	246	256	241
	7/1/76 - 7/31/76	26.9	19.4	16.2	14.2	0.02	1.43	-	-	224	249	241	241	242
	8/1/76 - 8/31/76	25.1	22.5	16.6	12.8	0.02	1.78	-	-	232	261	263	252	254
II	9/1/76 - 9/28/76	26.5	19.2	16.8	14.5	0.05	0.14	-	-	246	267	271	262	255
	10/7/76 - 10/31/76	29.6	21.0	19.0	18.4	0.12	0.12	-	-	245	254	249	257	257
	11/1/76 - 11/21/76	25.3	23.0	18.9	17.8	0.22	0.19	-	-	265	251	246	252	245
III	12/26/76 - 1/31/77	-	-	-	-	-	-	7.3	6.6	-	-	-	-	-
	3/8/77 - 3/28/77	33.5	23.0	23.4	20.8	0.18	0.07	7.3	6.7	246	252	248	252	225
IV	3/29/77 - 5/4/77	32.5	24.1	22.2	16.5	0.04	0.15	7.2	6.6	239	232	237	252	234
V	5/5/77 - 6/6/77	30.9	20.4	20.5	17.7	0.02	0.11	7.2	6.6	216	220	208	219	210
VI	6/7/77 - 7/4/77	30.3	19.7	18.1	18.7	0.02	0.07	7.4	6.7	241	236	227	231	231
	7/5/77 - 8/4/77	29.8	19.9	19.8	17.4	0.08	0.01	7.6	6.7	257	263	260	265	257
VII	8/5/77 - 9/7/77	28.5	17.7	19.3	15.7	0.05	0.03	7.3	6.6	238	234	227	234	239

* Median values reported.

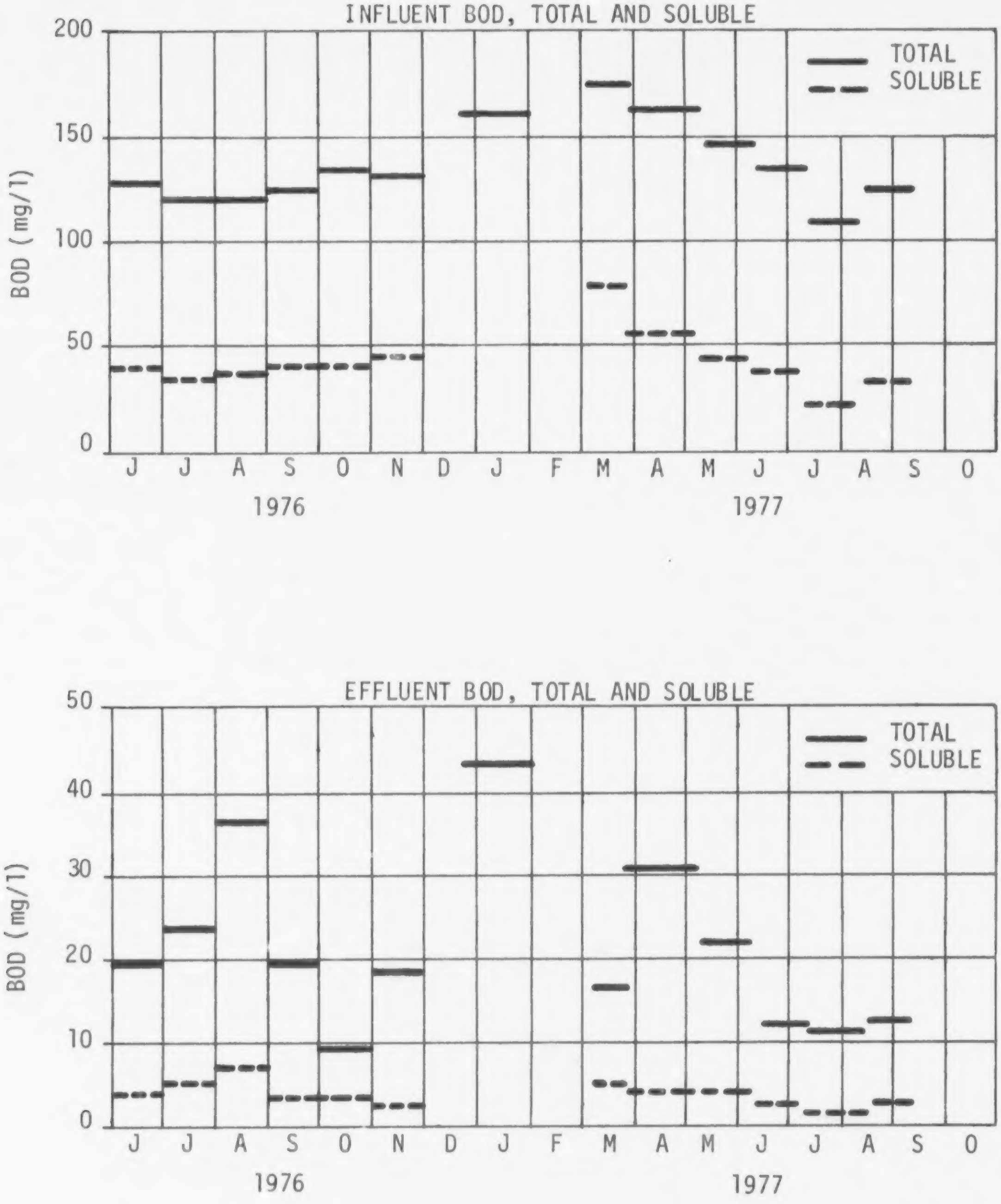
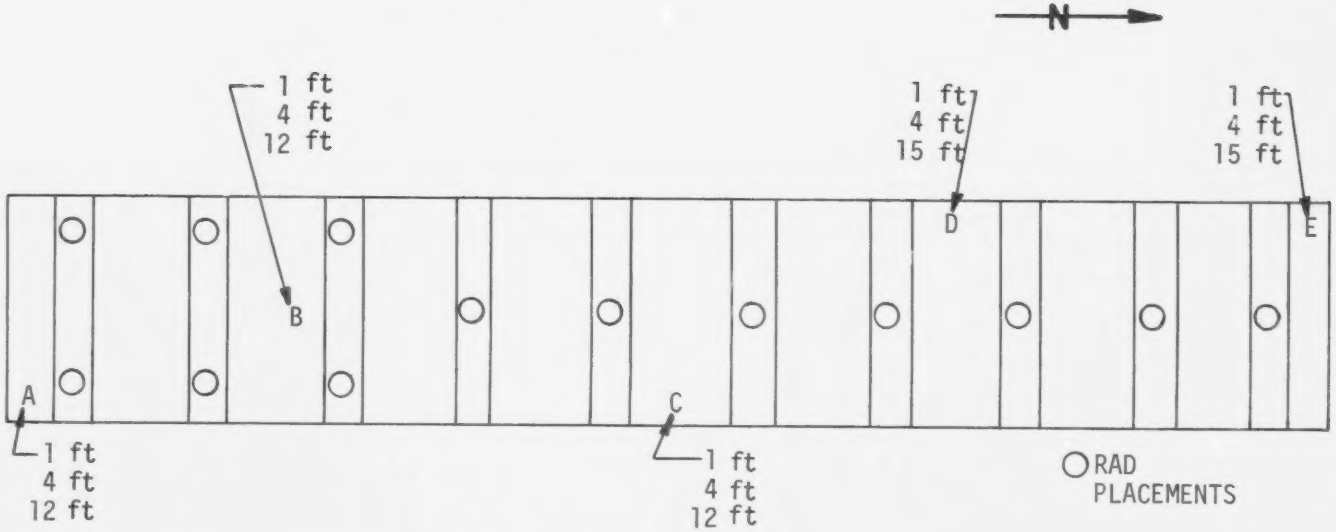


Figure 18. Total and soluble BOD.

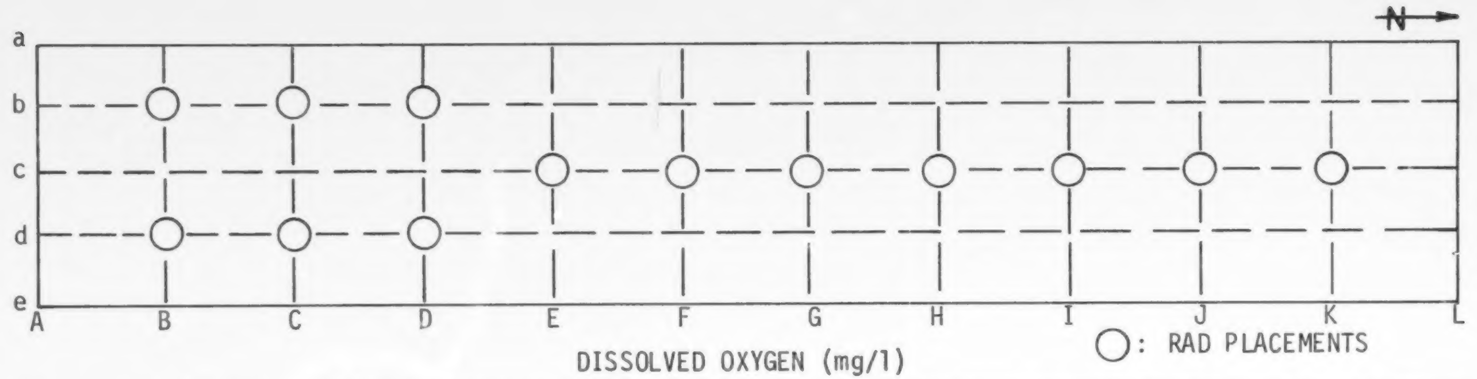


SAMPLE LOCATION	MLSS (mg/1)	SAMPLE LOCATION	MLSS (mg/1)	SAMPLE LOCATION	MLSS (mg/1)	SAMPLE LOCATION	MLSS (mg/1)	SAMPLE LOCATION	MLSS (mg/1)
A_1	3120	B_1	2760	C_1	2720	D_1	2760	E_1	3020
A_4	3920	B_4	2700	C_4	2840	D_4	3000	E_4	3360
A_{12}	2520	B_{12}	2760	C_{12}	2740	D_{15}	2920	E_{15}	3300

NOTE: 1 ft = 0.305 m

Figure 19. Suspended solids profile of the mixed liquor basin.

1976, to verify that aerobic conditions existed throughout the basin under normal operating conditions. The data presented in Figure 20 show the D.O. levels found at various locations in the basin. At the time of the profile, the D.O. set points in the basin ranged from 3 to 5 mg/l. Although notably high D.O. levels were recorded at locations "G" and "H", the result of a miscalibrated experimental D.O. control sensor, zero D.O. levels were not found anywhere in the basin. The lowest values noted, averaging approximately 0.7 mg/l, were found at location "A", the head end of the basin receiving both the influent wastewater and return sludge streams.



DEPTH	LOCATION	DISSOLVED OXYGEN (mg/l)											
		A	B	C	D	E	F	G	H	I	J	K	L
2 ft	a	0.2	2.5	3.0	3.4	3.4	5.2	5.9	8.4	7.6	6.2	4.6	3.0
	b	0.3	-	-	-	2.9	4.7	6.5	7.9	5.5	5.7	3.1	3.4
	c	-	1.4	4.9	3.1	-	-	-	-	-	-	-	-
	d	0.8	-	-	-	3.1	3.9	6.8	8.8	4.6	3.3	2.7	3.6
	e	0.8	1.4	2.5	4.3	3.1	4.6	6.5	7.9	4.7	3.7	4.1	4.3
6 ft	a	0.4	2.2	3.4	3.0	3.3	4.8	6.0	8.4	6.7	6.1	4.3	2.7
	b	0.2	-	-	-	2.9	4.4	6.3	7.4	5.7	5.0	3.1	3.3
	c	-	1.3	3.0	3.3	-	-	-	-	-	-	-	-
	d	1.0	-	-	-	3.0	3.9	6.4	9.1	4.7	3.4	2.8	3.8
	e	1.2	1.7	2.1	4.7	3.2	3.9	6.7	8.3	5.1	4.1	3.9	4.5
10 ft	a	0.4	3.2	2.8	3.5	3.2	5.2	5.7	8.3	6.6	6.3	4.0	2.7
	b	0.5	-	-	-	3.2	4.5	6.6	7.9	5.7	4.6	3.2	3.3
	c	-	1.6	1.7	3.2	-	-	-	-	-	-	-	-
	d	0.9	-	-	-	3.5	3.7	6.3	9.2	4.7	3.7	2.8	4.0
	e	1.0	1.5	1.2	4.7	3.1	4.1	6.6	9.4	5.4	4.5	3.2	4.4
14 ft	a	0.6	-	-	-	3.2	5.2	6.2	9.5	6.2	6.1	3.6	2.8
	b	1.0	-	-	-	-	-	-	-	-	-	-	3.1
	c	-	-	-	-	-	-	-	-	-	-	-	-
	d	0.9	-	-	-	-	-	-	-	-	-	-	4.1
	e	1.7	-	-	-	3.4	4.9	7.4	8.9	5.6	4.6	2.7	4.4

Figure 20. Dissolved oxygen profile of mixed liquor basin.

SECTION 14

EQUIPMENT PERFORMANCE AND RELIABILITY

As the first full-scale application of the FMC O_2 system, this demonstration provided an opportunity to evaluate various equipment items used in the open tank pure oxygen system. Where practicable, items from more than one supplier were tested to determine their reliability and performance.

ROTATING ACTIVE DIFFUSERS

A malfunctioning automatic epoxy dispenser used in the manufacture of the diffuser tile assemblies produced an epoxy mix that softened upon prolonged exposure to water. This resulted in leaks around the diffuser tile (2 percent of all tile installed) and, in some cases, actual displacement of tile sections from their holders (0.5 percent of all tile installed). The manufacturing process was subsequently amended, and 30 diffusers in operation at the Englewood-Littleton Wastewater Treatment Plant in Englewood, Colorado, have experienced no leaks in 15 mo of continuous operation.

ROTATING SEALS

The rotating seals used to connect the oxygen supply lines to the diffuser shafts were manufactured by Deublin Company. Failure of the seals caused by problems in material compatibility necessitated the replacement of all the seals with modified units prior to the completion of the demonstration. The original units used Buna-N "O" rings which tended to swell in the pure oxygen environment. In addition, the graphite-to-tool steel rotating surface used was not durable enough for the pure oxygen exposure, the graphite deteriorating into a lubricant that opened a leak path. The final configuration replaced the Buna-N "O" ring with a Viton seal, and changed the rotating surfaces to provide a copper-impregnated teflon surface to rotate against the tool steel. No failures occurred with the modified seals, and 30 of these seals have been in use at the Englewood-Littleton plant for a period of 15 mo without failure.

GEAR DRIVE UNITS

Five different gear drive units were employed to drive the RAD's used in the demonstration. Evaluation of these units included assessments of maintenance requirements, overall reliability, and measured horsepower. Units from three manufacturers (Chemineer, ProQuip and Morse Chain) were installed for the entire course of the demonstration, with an FMC unit evaluated for 13 mo and a U.S. Motors unit evaluated for only 1½ mo. Of all the units tested, only the

Morse Chain drive required no lubrication or oil change during the course of the demonstration; it also demonstrated superior overall reliability. The ProQuip drive suffered only a minor oil leak around one of the bearings, a problem which was readily corrected. The FMC drive, located in an area subject to considerable splashing from the influent sewage pumps, experienced a lip seal failure at the top bearing resulting from the abrasive materials in the influent. This failure could have been avoided through the use of a double lip seal to protect against the abnormal environment. The Chemineer drives had problems attributed to an undersizing of the output shaft bearings in the gear box. Near the end of the demonstration, these units were modified on site by replacing the upper drive bearings to increase the load carrying capacity of the drives. Thirty Chemineer units with the larger bearings are presently operating at the Englewood-Littleton plant, and after 15 mo of continuous operation have experienced no failures.

On two occasions, measurements were made of the power requirements for each of the installed drives to determine actual draw horsepower. Since not all drive units were running at the same rpm, a correction factor was applied to convert the measured horsepower for all units to 82.6 rpm*. Table 10 summarizes the information obtained for the drive units used during the demonstration.

TABLE 10. GEAR DRIVE POWER REQUIREMENTS

Drive Location	Manufacturer	rpm	Correction Factor to 82.6 rpm	Measured hp°	Corrected hp°
1	Chemineer	85.5	0.9066	8.06	7.31
2	FMC	82.6	1.0000	6.84	6.84
2	U.S. Motors	84.0	0.9534	+	+
3	Chemineer	85.5	0.9066	7.94	7.20
4	Chemineer	85.5	0.9066	7.80	7.07
5	Chemineer	85.5	0.9066	7.90	7.16
6	Chemineer	85.5	0.9066	7.94	7.20
7	Chemineer	85.5	0.9066	7.98	7.24
8	Chemineer	85.5	0.9066	7.80	7.07
9	Chemineer	85.5	0.9066	8.02	7.27
10	Chemineer	85.5	0.9066	7.55	6.84
11	Chemineer	85.5	0.9066	7.83	7.09
12	ProQuip	84.4	0.9406	6.84	6.44
13	Morse Chain	74.0	1.3665	7.54	10.30

° 1 hp = 0.746 kW

+ Not available

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* Arbitrarily standardized at the rpm of the FMC drive.

DISSOLVED OXYGEN SENSORS

Five D.O. sensors supplied by different manufacturers were evaluated during the demonstration. Four were polarographic types employing a teflon membrane and electrolyte in the sensor element. Of these, three were equipped with mechanical agitators to provide the mixed liquor velocity required for accurate measurement and cleansing of the membrane.

It was apparent in mid-July 1976 that the polarographic sensors were causing operational problems. Agitator failure caused by debris clogging the mechanisms resulted in membrane fouling. This caused the sensors to show lower D.O. levels than were actually present in the basin and resulted in excess oxygen usage and high basin D.O. levels. The problem was corrected by an FMC modification using an air-lift mechanism to induce a mixed liquor stream past the membrane face in lieu of the mechanical agitator previously used. This modification decreased the maintenance requirements considerably and increased the reliability of the sensors. Of the polarographic sensors used, one unit, manufactured by Weston and Stack, was judged superior to the others in this demonstration on the basis of large membrane surface exposure, sufficient reservoir of electrolyte, and adaptability to the air-lift mechanism used in the modified configuration.

The fifth sensor tested was a unit using bi-metallic surfaces to produce a current flow dependent upon the D.O. level, with an abrasive rotating arm used to continually clean the active surfaces. The principal advantage of this unit was the elimination of the membrane and electrolyte, the most common maintenance items of polarographic sensors. The performance of the unit, however, was not sufficiently good to recommend it in future applications. Metal from the sensor clogged the abrasive surface of the cleaning bar, rendering it ineffective. This allowed deposits to form on the bi-metallic surfaces and resulted in erroneous readings. Two sensor assemblies with different metals were used, but neither provided the reliability needed.

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APPENDIX A

DAILY OPERATING DATA

Appendix A is a computerized daily operating record of the demonstration project and shows those analyses used for process control and as indicators of process performance. The data are grouped by calendar months, rather than by phases and periods as in the body of this report. Due to alterations in the computer program necessitated by dual clarifier operation begun in March 1977, two sets of data sheets are shown for this month.

Entries of "-1" in the data tables indicate the absence of data, due either to sampler malfunction or personnel error. Data have been edited only where necessary to correct for the miscalibration of metering devices.

Caution should be observed in interpreting average results shown in the tables. The averages given are simple numeric means of the tabulated daily data, and these may not equate with overall performance for certain calculated quantities. As an example, consider 2 day's data for calculating lb O_2/lb BOD_R:

Day 1: 10,000 lb O_2/5,000 lb BOD_R = 2 lb O_2/lb BOD_R

Day 2: 10,000 lb O_2/10,000 lb BOD_R = 1 lb O_2/lb BOD_R

The average of the above values on the right side of the equations would be 1.5 lb O_2/lb BOD_R, while on an overall consumption basis, the average value would be 20,000 lb O_2/15,000 lb BOD_R = 1.33 lb O_2/lb BOD_R.

The trade name MAROX is used throughout Appendices A and B to denote the open tank pure oxygen activated sludge system discussed in this report.

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JUNE 1976

MAROX FLOWS AND CONCENTRATIONS

	*********SECONDARY INFLUENT*********						****RETURN SOLIDS****				********MIXED LIQUOR*********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
6/ 1	9.5	94	3.7	97	137	5.4	4.1	43	9200	7720	17	2630	2220	2.8	59	0.068	2.6
6/ 2	9.5	97	3.8	100	139	5.5	3.8	40	10600	8800	15	2940	2410	2.5	88	0.042	1.9
6/ 3	9.5	105	4.2	99	140	5.5	3.7	39	11200	9600	18	3240	2750	2.9	80	0.077	3.6
6/ 4	9.5	92	3.6	102	146	5.8	3.8	40	12320	10240	18	3100	2580	3.2	67	0.069	3.5
6/ 5	9.5	83	3.3	88	122	4.8	3.6	40	11700	9600	20	3220	2630	2.7	75	0.068	3.3
6/ 6	9.5	73	2.9	72	118	4.3	3.8	40	11800	9800	20	3070	2550	2.7	74	0.067	3.3
6/ 7	9.5	93	3.7	92	121	4.8	3.8	40	10300	8500	20	3000	2440	2.8	61	0.066	2.8
6/ 8	9.1	90	3.4	92	127	4.8	3.9	43	12800	10600	20	3050	2520	2.7	71	0.058	3.1
6/ 9	9.3	107	4.1	104	151	5.9	3.8	41	11200	9160	20	3170	2580	2.7	69	0.057	2.7
6/10	8.8	97	3.6	92	147	5.4	3.7	42	11300	9420	20	3040	2480	2.4	62	0.039	1.8
6/11	9.1	113	4.3	105	164	6.2	3.7	41	11700	9700	20	3210	2670	1.9	81	0.046	2.2
6/12	9.0	78	2.9	90	117	4.4	3.7	41	10900	9000	20	3230	2610	2.9	96	0.043	2.0
6/13	9.6	76	3.0	81	98	3.9	3.8	40	10900	8920	20	3270	2640	2.8	83	0.042	1.9
6/14	9.9	85	3.5	93	131	5.4	3.8	38	10500	8680	20	2920	2350	2.6	96	0.034	1.5
6/15	9.8	85	3.5	88	148	6.0	3.8	39	11200	9120	20	3020	2550	2.6	77	0.031	1.4
6/16	10.2	104	4.4	94	139	5.9	3.8	37	11400	9600	20	2800	2350	2.5	73	0.040	1.9
6/17	10.0	101	4.2	94	145	6.3	3.6	36	10600	8800	20	3530	2920	2.6	80	0.032	1.4
6/18	9.8	90	3.7	86	121	4.9	3.8	39	10800	9000	19	3000	-1	2.3	71	0.027	1.2
6/19	10.1	84	3.5	76	99	4.2	3.8	38	11600	9600	20	3310	2730	2.5	77	0.079	3.8
6/20	10.1	72	3.0	64	97	4.1	3.6	36	11300	9400	20	3050	2460	2.5	79	0.102	4.8
6/21	9.8	75	3.1	84	108	4.4	3.8	39	10900	9000	19	3020	2500	2.2	82	0.048	2.2
6/22	9.5	61	2.4	81	123	4.9	3.8	40	11400	9400	20	3000	2430	2.0	87	0.042	2.0
6/23	9.7	65	3.4	84	138	5.6	3.8	39	10600	8900	21	3210	2640	2.0	85	0.042	1.9
6/24	9.3	95	3.7	78	134	5.2	3.9	42	9680	8120	20	3010	2530	2.8	91	0.045	1.6
6/25	9.4	81	3.2	76	126	4.9	3.9	41	10200	8400	19	2890	2360	2.6	82	0.054	2.3
6/26	9.4	74	2.9	65	86	3.4	3.9	41	10530	8500	19	3000	2430	2.3	85	0.065	2.8
6/27	9.4	69	2.7	74	90	3.5	3.8	40	10200	8400	19	2870	2350	2.7	80	0.086	3.7
6/28	9.4	75	2.9	80	110	4.3	3.6	40	9720	8200	21	2660	2370	3.4	83	0.062	3.3
6/29	9.5	100	4.0	86	130	5.1	3.8	40	11600	10000	21	3270	2750	3.1	90	0.063	3.0
6/30	9.3	92	3.6	99	124	4.8	3.8	41	10800	9500	21	3060	2560	3.9	87	0.049	2.2
TOTAL	286.0		104.3			149.6	114.3									1.663	76.1
AVER.	9.5	88	3.5	87	126	5.0	3.8	40	10971	9119	20	3066	2530	2.7	79	0.055	2.5

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JUNE 1976

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
DATE	# BOD /KCF	#O2/ #BODR	F/M BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	BASIN SS TONS	CLAR SS TONS	TOTAL SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
6/ 1	122.8	1.21	0.89	0.02	0.83	789	15.77	22.58	4.6	7.25	12.55	19.80	5.2	30	1.2	28	22	0.9	68	84
6/ 2	124.6	1.42	0.83	0.31	1.12	789	17.63	24.68	4.3	8.10	13.73	21.83	6.7	36	1.4	33	19	0.8	63	86
6/ 3	125.5	1.56	0.73	0.10	0.98	789	19.43	27.00	3.6	8.93	12.71	21.64	4.5	31	1.2	32	21	0.8	70	85
6/ 4	130.9	1.41	0.81	0.11	0.83	789	18.59	26.03	3.0	8.54	12.29	20.84	4.2	37	1.5	34	18	0.7	60	88
6/ 5	109.4	1.72	0.67	0.32	1.17	789	19.31	27.04	3.1	8.88	11.94	20.82	4.6	31	1.2	34	24	1.0	63	80
6/ 6	96.8	1.80	0.61	0.92	1.79	789	18.41	25.78	3.6	8.46	13.39	21.86	4.4	41	1.6	33	24	1.0	44	78
6/ 7	108.5	1.39	0.71	-1.26	-0.33	789	17.99	25.19	1.9	8.27	7.69	15.96	3.5	44	1.7	36	21	0.8	53	83
6/ 8	109.1	1.35	0.69	0.26	1.05	756	17.52	25.03	1.3	8.41	7.80	16.20	3.8	31	1.2	32	14	0.5	66	89
6/ 9	132.5	1.12	0.82	-0.33	0.50	772	18.61	26.22	1.0	8.74	6.05	14.79	3.8	32	1.2	30	22	0.9	72	85
6/10	122.1	1.34	0.79	0.12	0.91	731	16.89	23.99	1.5	8.38	7.40	15.78	5.1	35	1.3	32	24	0.9	64	84
6/11	140.9	1.14	0.65	-0.16	0.65	756	18.44	25.94	1.1	8.85	6.59	15.44	4.1	40	1.5	34	25	0.9	65	85
6/12	99.4	1.56	0.61	0.01	0.82	747	18.35	25.90	1.1	8.90	6.14	15.04	4.5	37	1.4	30	21	0.8	53	82
6/13	88.8	1.54	0.54	0.08	1.01	797	19.82	27.66	1.2	9.01	6.39	15.40	5.2	26	1.0	24	16	0.6	66	84
6/14	122.4	1.18	0.83	-0.30	0.46	822	18.25	25.25	1.4	8.05	6.64	14.69	5.2	33	1.4	30	19	0.8	61	85
6/15	136.9	1.09	0.86	0.04	0.70	814	18.68	25.93	1.6	8.32	7.59	15.92	6.4	25	1.0	32	19	0.8	71	87
6/16	133.8	1.17	0.91	-0.54	0.32	847	18.03	24.75	1.2	7.72	6.68	14.40	4.6	29	1.2	28	18	0.8	72	87
6/17	136.9	1.20	0.75	0.44	1.27	830	22.28	30.75	2.0	9.73	8.15	17.88	6.0	37	1.5	28	23	1.0	63	84
6/18	111.9	1.36	-1.60	0.41	1.33	814	18.56	25.76	3.6	8.27	12.26	20.53	7.6	36	1.5	30	23	0.9	60	81
6/19	94.4	1.49	0.55	0.36	1.41	839	21.10	29.05	2.8	9.12	11.05	20.17	3.9	31	1.3	34	19	0.8	63	81
6/20	92.5	1.51	0.60	-0.16	0.74	839	19.45	26.70	1.8	8.41	8.18	16.58	2.7	30	1.3	26	17	0.7	58	82
6/21	99.9	1.29	0.64	-0.10	0.74	814	18.68	25.93	1.7	8.32	7.64	15.96	4.8	28	1.1	24	18	0.7	63	83
6/22	110.3	1.24	0.73	0.10	0.67	789	17.99	25.19	1.5	8.27	7.47	15.74	5.1	27	1.1	24	16	0.6	56	87
6/23	126.3	1.12	0.77	0.52	1.22	805	19.66	27.36	2.8	8.85	10.28	19.13	7.3	18	0.7	24	16	0.6	79	88
6/24	117.6	1.24	0.75	-0.33	0.49	772	17.67	25.08	3.4	8.30	10.55	18.84	7.6	17	0.7	21	18	0.7	82	87
6/25	111.8	1.27	0.75	0.87	1.60	780	17.15	24.26	5.0	7.97	14.84	22.81	7.6	18	0.7	20	15	0.6	78	88
6/26	76.3	1.84	0.50	0.04	1.07	780	17.80	25.19	4.4	8.27	13.84	22.11	6.0	22	0.9	24	14	0.5	70	84
6/27	79.9	1.61	0.54	0.03	0.99	780	17.03	23.92	4.0	7.91	12.51	20.42	4.6	21	0.8	24	18	0.7	70	80
6/28	97.6	1.40	0.66	-0.50	0.27	780	16.97	23.83	2.8	7.88	9.26	17.14	4.0	25	1.0	25	13	0.5	67	86
6/29	116.6	1.19	0.68	0.44	1.35	789	19.61	27.46	2.2	9.01	9.45	18.47	4.1	37	1.5	32	21	0.8	62	84
6/30	108.8	1.43	0.68	-0.56	0.34	772	17.97	25.31	1.9	8.43	8.06	16.50	5.0	29	1.1	33	22	0.9	68	82
TOTAL										253.56	289.12	542.68			36.3			23.0		
AVER.	112.8	1.37	0.72	0.04	0.88	791	18.46	25.83	2.5	8.45	9.64	18.09	5.1	30	1.2	29	19	0.8	65	84

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/17/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JULY 1976

MAROX FLOWS AND CONCENTRATIONS

	*********SECONDARY INFLUENT*********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
	FLOW	SS	SS	TOC	BOD	BOD	FLOW		SS	VSS	TEMP	SS	VSS	DO	SVI	FLOW	SS
DATE	MGD	MG/L	TONS	MG/L	MG/L	TONS	MGD	%	MG/L	MG/L	C	MG/L	MG/L	MG/L		MCD	TONS
7/ 1	9.5	93	3.7	93	124	4.9	3.6	40	11300	6600	21	3090	2610	2.8	74	0.046	2.2
7/ 2	9.4	90	3.5	89	107	4.2	3.8	40	11800	9600	21	3450	2840	2.6	78	0.044	2.2
7/ 3	9.5	90	3.6	89	72	2.9	3.9	41	12500	9000	21	3380	2770	2.3	78	0.045	2.3
7/ 4	9.5	74	2.9	66	81	3.2	3.8	40	10900	9100	19	3150	2640	3.3	70	0.044	2.0
7/ 5	9.4	63	2.5	72	107	4.2	3.8	40	10900	9200	19	3100	2570	3.2	73	0.041	1.9
7/ 6	9.5	83	3.3	89	136	5.4	3.8	40	11200	9300	20	3070	2580	2.4	80	0.041	1.9
7/ 7	9.3	83	3.2	100	152	5.9	3.8	41	11200	9300	22	3000	2520	2.3	69	0.045	2.1
7/ 8	9.1	80	3.0	80	130	4.9	3.7	41	11400	9600	19	3150	2660	3.1	75	0.049	2.3
7/ 9	9.4	82	3.2	80	114	4.5	3.7	39	11100	9400	18	3040	2540	2.9	79	0.048	2.2
7/10	9.9	80	3.3	73	121	5.0	3.5	35	11500	9800	20	2870	2370	2.3	71	0.052	2.6
7/11	9.7	70	2.8	68	103	4.2	3.4	35	11600	9700	20	2940	2470	2.4	80	0.057	2.8
7/12	9.7	75	3.0	74	106	4.3	3.4	35	11700	9900	20	2860	2390	2.1	97	0.057	2.8
7/13	9.6	84	3.4	84	123	4.9	3.5	36	11300	9800	20	2760	2420	3.4	97	0.056	2.6
7/14	9.5	80	3.2	88	130	5.1	3.4	36	12400	10700	21	2720	2330	-1.0	77	0.063	3.3
7/15	9.6	84	3.4	90	127	5.1	3.6	38	11200	9470	22	2660	2260	-1.0	113	0.065	3.0
7/16	9.5	86	3.4	94	134	5.3	3.8	40	10500	9000	21	2730	2380	2.9	77	0.088	3.9
7/17	9.5	78	3.1	74	117	4.6	3.8	40	9160	7920	21	2520	2120	-1.0	104	0.094	3.6
7/18	9.6	74	3.0	74	104	4.2	3.6	38	9850	8450	22	2500	2120	-1.0	113	0.086	3.5
7/19	9.4	86	3.4	94	117	4.6	3.5	37	10400	8900	22	2230	1900	2.6	96	0.078	3.4
7/20	9.6	89	3.6	91	115	4.6	3.5	36	10250	8600	22	2150	1770	3.3	104	0.067	2.9
7/21	9.5	98	3.9	86	124	4.9	3.6	38	10100	8200	21	1930	1620	2.4	100	0.071	3.0
7/22	9.2	92	3.5	86	124	4.8	4.0	43	9560	7920	22	2400	1980	9.0	95	0.081	3.2
7/23	9.3	84	3.3	87	134	5.2	4.1	44	8880	7520	22	2550	2130	-1.0	142	0.107	4.0
7/24	9.3	70	2.7	78	109	4.2	4.1	44	8800	7440	19	2580	2120	15.5	103	0.100	3.7
7/25	9.6	86	3.4	76	92	3.7	4.2	44	9000	7400	20	2520	2120	-1.0	103	0.094	3.5
7/26	9.2	87	3.3	77	116	4.5	4.0	43	6600	7160	21	2620	2170	9.3	110	0.076	2.7
7/27	9.3	87	3.4	82	113	4.4	4.1	44	9400	8040	21	2540	2160	6.1	117	0.060	2.4
7/28	9.4	84	3.3	86	137	5.4	4.1	44	8280	6920	21	2330	2000	18.2	145	0.052	1.8
7/29	9.6	96	3.8	86	119	4.8	4.2	44	8480	7160	21	2350	1990	17.5	111	0.068	2.4
7/30	9.1	103	3.9	96	111	4.2	3.8	42	8440	7000	22	2320	1910	-1.0	94	0.091	3.2
7/31	9.3	84	3.3	74	104	4.0	3.9	42	7600	6200	22	2090	1720	3.8	106	0.104	3.3
TOTAL	293.0		102.2			141.9	117.2									2.070	86.5
AVER.	9.5	84	3.3	83	116	4.6	3.8	40	10310	8526	21	2697	2265	5.2	95	0.067	2.8

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/17/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JULY 1976

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
DATE	# BOD /KCF	#O2/ #BODR	F/M BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	BASIN SS TONS	CLAR SS TONS	TOTAL SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
7/ 1	111.2	1.36	0.68	-0.07	0.82	789	18.53	25.94	2.0	8.52	8.69	17.21	5.1	31	1.2	33	19	0.8	67	85
7/ 2	94.9	1.57	0.54	0.49	1.50	780	20.47	28.75	2.1	9.51	9.35	18.86	5.3	36	1.4	31	18	0.7	60	83
7/ 3	64.6	2.69	0.37	0.11	1.63	789	20.27	28.59	2.1	9.32	9.90	19.22	5.6	28	1.1	26	13	0.5	69	82
7/ 4	72.6	2.17	0.44	-0.74	0.39	789	18.89	26.45	2.1	8.68	8.63	17.32	5.9	23	0.9	16	15	0.6	69	81
7/ 5	94.9	1.56	0.59	-0.09	0.65	780	16.40	25.83	2.0	8.54	8.38	16.93	6.6	18	0.7	22	21	0.8	71	80
7/ 6	121.9	1.31	0.76	-0.11	0.60	789	18.41	25.78	2.0	8.46	8.62	17.08	6.5	18	0.7	25	20	0.8	78	85
7/ 7	133.4	1.25	0.85	0.00	0.62	772	17.61	24.81	2.3	8.27	9.38	17.65	6.7	14	0.5	28	19	0.7	83	88
7/ 8	111.7	1.30	0.67	0.09	0.79	756	18.10	25.45	2.3	8.68	9.55	18.23	6.4	14	0.5	21	15	0.6	82	88
7/ 9	101.1	1.42	0.64	-0.02	0.80	780	18.04	25.14	2.7	8.38	10.32	18.69	6.9	12	0.5	18	14	0.5	85	88
7/10	113.1	1.28	0.76	0.71	1.47	822	17.94	24.28	3.8	7.91	13.93	21.84	6.8	16	0.7	21	16	0.7	80	87
7/11	94.3	1.64	0.61	0.47	1.30	805	18.00	24.31	4.2	8.10	14.76	22.06	6.7	16	0.6	18	19	0.8	77	82
7/12	97.0	1.52	0.65	0.01	0.84	805	17.51	23.65	4.1	7.88	14.62	22.50	6.6	16	0.6	18	16	0.6	79	65
7/13	111.5	1.41	0.74	-0.03	0.76	797	16.73	22.82	4.4	7.61	14.89	22.50	6.9	15	0.6	24	16	0.6	82	87
7/14	116.6	1.40	0.80	0.92	1.66	789	16.31	22.15	5.0	7.50	18.04	25.54	6.3	20	0.8	24	22	0.9	75	83
7/15	115.1	1.54	0.82	0.50	1.32	797	16.12	22.17	6.2	7.33	19.37	26.70	6.3	30	1.2	24	25	1.0	64	80
7/16	120.2	1.69	0.81	0.34	1.25	789	16.37	22.92	6.1	7.52	17.92	25.45	4.3	53	2.1	38	39	1.5	38	71
7/17	104.9	1.47	0.79	-0.40	0.42	789	15.11	21.16	6.1	6.95	15.63	22.58	5.1	22	0.9	26	22	0.9	72	81
7/18	94.2	1.73	0.71	-0.03	0.87	797	15.15	20.83	5.0	6.89	14.33	21.22	5.0	17	0.7	22	22	0.9	77	79
7/19	103.6	1.72	0.88	0.36	1.31	780	13.23	18.16	5.2	6.15	15.61	21.76	5.3	19	0.7	24	26	1.0	78	78
7/20	104.2	1.70	0.94	-0.15	0.82	797	13.03	17.78	5.1	5.93	15.15	21.08	5.7	21	0.8	25	23	0.9	76	80
7/21	111.2	1.64	1.10	0.27	1.27	789	11.57	15.96	5.9	5.32	16.78	22.10	5.7	23	0.9	22	26	1.0	77	79
7/22	107.7	1.77	0.87	0.39	1.37	764	13.94	20.00	5.9	6.62	15.88	22.49	5.0	34	1.3	27	30	1.2	63	76
7/23	117.6	1.54	0.89	0.17	0.94	772	14.97	21.57	5.7	7.03	14.34	21.37	4.2	30	1.2	24	24	0.9	64	82
7/24	95.7	2.12	0.72	0.23	1.08	772	15.15	21.82	5.2	7.11	13.21	20.32	4.5	21	0.8	22	27	1.0	70	75
7/25	83.4	2.14	0.63	-0.40	0.78	797	15.27	21.95	4.2	6.95	11.45	18.40	4.4	17	0.7	29	19	0.8	80	79
7/26	100.7	1.77	0.74	-0.63	0.26	764	15.22	21.83	3.2	7.22	8.98	16.20	5.1	12	0.5	18	19	0.7	86	84
7/27	99.2	1.63	0.74	0.46	1.39	772	14.91	21.49	3.9	7.00	11.31	18.32	6.2	15	0.6	22	19	0.7	83	83
7/28	121.6	1.77	0.97	0.49	1.29	780	13.63	19.86	6.0	6.42	13.94	20.36	6.3	37	1.5	28	32	1.3	56	77
7/29	107.8	2.48	0.87	0.67	1.84	797	14.24	20.47	6.2	6.48	14.67	21.14	4.0	71	2.8	35	37	1.5	26	69
7/30	95.3	2.18	0.80	0.97	2.35	756	13.33	18.89	6.8	6.39	15.76	22.15	3.9	65	2.5	41	36	1.4	37	68
7/31	91.3	2.65	0.85	-0.82	0.37	772	12.27	17.42	5.5	5.76	11.93	17.69	3.2	56	2.2	33	33	1.3	33	68
TOTAL										230.43	405.34	635.77			32.3			27.6		
AVER.	103.6	1.72	0.75	0.13	1.06	785	16.09	22.52	4.3	7.43	13.08	20.51	5.6	26	1.0	25	23	0.9	69	80

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: AUGUST 1976

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY	INFLUENT********					****RETURN	SOLIDS****			*******MIXED	LIQUOR********				***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
8/ 1	9.4	86	3.4	66	81	3.2	3.9	41	7800	6560	22	2110	1740	4.7	119	0.091	3.0
8/ 2	9.4	93	3.6	90	101	4.0	3.9	41	9230	7630	22	2280	1870	5.8	140	0.066	2.5
8/ 3	8.0	90	3.0	81	114	3.8	3.9	49	9800	8120	22	2410	1990	3.0	159	0.058	2.4
8/ 4	8.1	95	3.2	88	129	4.4	3.9	48	8480	7040	22	2740	2220	2.6	166	0.072	2.5
8/ 5	8.9	99	3.7	82	123	4.6	3.9	44	10200	8300	22	2640	2060	2.1	132	0.073	3.1
8/ 6	9.2	89	3.4	85	121	4.6	3.4	37	10100	8300	22	2780	2270	1.8	155	0.070	2.9
8/ 7	9.1	79	3.0	80	96	3.6	3.6	40	10200	8300	22	2830	2280	2.2	172	0.084	3.6
8/ 8	9.0	77	2.9	72	97	3.6	3.6	40	9530	7800	22	2770	2260	2.0	197	0.087	3.5
8/ 9	9.1	82	3.1	77	132	5.0	3.6	40	8300	6770	22	2640	2190	2.0	216	0.090	3.1
8/10	8.5	110	3.9	98	97	3.4	3.5	41	8840	7320	22	2520	2150	2.1	164	0.079	2.9
8/11	9.1	87	3.3	88	121	4.6	3.7	41	7840	6840	22	2090	1790	1.8	193	0.080	2.6
8/12	9.1	83	3.3	90	129	4.9	3.8	42	7760	6600	22	1800	1510	1.5	200	0.094	3.0
8/13	9.3	99	3.8	97	132	5.1	4.2	45	5880	4800	22	1820	1520	2.2	245	0.077	1.9
8/14	8.5	78	2.8	78	104	3.7	4.5	53	7280	6320	22	1960	1590	2.0	240	0.044	1.3
8/15	8.1	70	2.4	75	99	3.3	4.5	56	9080	7680	22	1910	1550	2.4	261	0.034	1.3
8/16	7.6	116	3.7	90	127	4.0	3.6	47	7080	5880	22	2000	2050	2.3	177	0.079	2.3
8/17	7.6	130	4.1	100	122	3.9	3.9	51	8040	6560	22	2160	1820	2.0	169	0.081	2.7
8/18	7.1	88	2.6	90	121	3.6	3.9	55	8560	7320	22	2110	1770	2.3	172	0.101	3.6
8/19	7.1	86	2.5	103	137	4.1	4.0	56	6720	5560	23	2330	1890	4.0	218	0.064	1.8
8/20	7.6	76	2.4	83	111	3.5	3.9	51	5880	4820	21	1930	1610	1.0	180	0.090	2.2
8/21	8.3	76	2.6	80	92	3.2	3.9	47	5360	4600	22	1580	1290	0.8	253	0.093	2.1
8/22	8.8	69	2.5	72	98	3.6	3.9	44	4380	3740	22	1570	1290	1.0	200	0.078	1.4
8/23	9.0	91	3.4	90	124	4.7	3.9	43	4200	3790	22	1290	1120	1.5	333	0.042	0.7
8/24	5.1	165	3.5	111	132	2.8	1.6	31	3800	3400	22	1350	1160	1.4	-1	0.018	0.3
8/30	4.0	111	1.9	109	157	2.6	6.0	150	10300	8200	22	2550	2040	0.4	219	-1.000	-1.0
8/31	8.7	90	3.3	91	128	4.6	3.4	39	11600	9400	22	2630	2080	0.4	180	0.005	0.2
TOTAL	213.7		81.4			102.4	99.9									1.750	57.1
AVER.	8.2	93	3.1	87	116	3.9	3.8	49	7932	6602	22	2185	1812	2.1	194	0.070	2.3

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

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          10/18/77                        METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1          PERIOD: AUGUST 1976

                                                 MAROX LOADING, INVENTORY AND PERFORMANCE

        ********AERATION BASIN********   ******CLARIFIER*******      ********INVENTORY********     ***SECONDARY EFFLUENT*** *% REM*
                          F/M                                        BASIN  CLAR  TOTAL
        # BOD  #O2/   BOD/  BIOSYNTHESIS  OVERFLOW   FLUX      DOB    SS     SS     SS    SRT     SS   SS   TOC  BOD  BOD    SS BOD
 DATE   /KCF  #BODR  MLVSS   NET  GROSS   G/SF/DY  #/SF/DAY    FT    TONS   TONS   TONS  DAYS   MG/L TONS MG/L MG/L TONS
                                                   Q     Q+R

 8/ 1   71.9   2.64  0.66   0.22   1.75     780   12.52 17.72 5.2    5.62  11.71  17.52  4.4     27  1.1   21   25  1.0    69 69
 8/ 2   89.6   1.95  0.77   0.17   1.29     780   13.53 19.14 4.5    6.28  12.38  18.66  6.1     13  0.5   26   18  0.7    56 82
 8/ 3   86.1   1.67  0.69   0.19   1.11     664   12.17 18.10 4.4    6.64  12.92  19.56  7.1     11  0.4   20   16  0.5    88 86
 8/ 4   98.6   1.55  0.71  -0.92  -0.06     672   14.01 20.76 3.2    7.55   8.65  16.40  5.6     12  0.4   28   19  0.6    87 85
 8/ 5  103.3   1.65  0.80   0.89   1.66     739   14.83 21.33 4.1    7.28  12.74  20.02  5.8     10  0.4   12   20  0.7    90 84
 8/ 6  105.1   1.40  0.74  -0.06   0.79     764   16.15 22.11 3.9    7.66  12.16  19.82  5.9     11  0.4   16   17  0.7    88 85
 8/ 7   82.5   2.05  0.58   1.06   2.06     756   16.26 22.69 4.7    7.80  14.14  21.94  5.4     13  0.5   27   17  0.6    84 82
 8/ 8   82.4   2.25  0.58  -0.41   0.58     747   15.74 22.03 4.2    7.64  12.12  19.76  5.1     11  0.4   16   19  0.7    86 80
 8/ 9  113.4   1.43  0.83  -0.41   0.31     756   15.17 21.17 4.1    7.28  10.37  17.65  5.1      9  0.3   16   18  0.7    89 86
 8/10   77.8   2.12  0.58   0.66   2.07     706   13.52 19.09 4.9    6.95  12.66  19.61  5.2     24  0.9   25   19  0.7    78 82
 8/11  103.9   2.10  0.93   2.07   3.35     756   12.01 16.89 6.7    5.76  14.46  20.22  2.5    143  5.4   59   53  2.0   -63 56
 8/12  110.8   1.81  1.18   0.52   1.62     756   10.34 14.66 6.6    4.96  14.13  19.09  3.2     79  3.0   44   49  1.9    10 62
 8/13  115.9   1.69  1.22   0.37   1.66     772   10.69 15.51 7.2    5.02  11.51  16.53  2.2    145  5.6   55   55  2.1   -45 58
 8/14   83.4   2.02  0.84   2.16   3.26     706   10.52 16.09 8.0    5.40  15.59  20.99  5.6     68  2.4   35   33  1.2    13 68
 8/15   75.7   2.16  0.78   0.34   1.34     672    9.77 15.19 6.4    5.26  16.12  21.38  7.7     44  1.5   28   29  1.0    37 71
 8/16   91.1   1.39  0.71  -1.95  -0.88     631    9.60 14.14 5.0    5.51  10.30  15.82  6.3      6  0.2   17   18  0.6    95 85
 8/17   87.5   0.18  0.77   1.39   2.72     631   10.36 15.68 6.8    5.95  15.01  20.96  6.4     18  0.6   20   24  0.8    86 83
 8/18   81.1   1.90  0.73   0.37   1.27     589    9.46 14.65 6.1    5.82  14.61  20.43  4.8     21  0.6   24   23  0.7    76 81
 8/19   91.8   1.61  0.78  -0.19   0.74     589   10.44 16.33 6.7    6.42  12.39  18.81  5.2     62  1.8   47   45  1.3    28 67
 8/20   79.6  33.84  0.79  46.85  65.85     631    9.26 14.01 7.7    5.32  12.19  17.51  1.8    235  7.4   99  107  3.4  -208  4
 8/21   72.1   4.30  0.90   2.91   5.73     689    8.28 12.17 7.8    4.36  11.23  15.59  2.1    150  5.2   70   65  2.2   -96 29
 8/22   81.4   2.19  1.01   0.35   1.92     731    8.72 12.59 8.1    4.33   9.48  13.81  2.8     94  3.4   52   54  2.0   -35 45
 8/23  105.3   2.08  1.51   0.24   2.06     747    7.33 10.51 7.3    3.56   8.32  11.88  2.0    135  5.1   72   74  2.8   -47 40
 8/24   63.5  -1.00  0.88  -1.00  -1.00     423    4.35  5.71-1.0    3.72  -1.00  -1.00 -1.0    106  2.3   62   67  1.4    36 49
 8/30   59.3  -1.00  0.47  -1.00  -1.00     332    6.44 16.10-1.0    7.03  -1.00  -1.00 -1.0     96  1.6   51   31  0.5    14 80
 8/31  135.1   1.27  0.81  -1.00  -1.00     722   14.44 20.09 1.5    7.25   7.60  14.85 13.8     23  0.8   26   22  0.8    74 83

TOTAL                                                               156.56 292.99 438.80              52.2           31.6

AVER.   89.2   3.24  0.82   2.47   4.45     682   11.38 16.71 5.6    6.02  12.21  18.28  5.1     60  2.0   37   36  1.2    31 69



-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS
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10/17/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: SEPTEMBER 1976

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
	FLOW	SS	SS	TOC	BOD	BOD	FLOW		SS	VSS	TEMP	SS	VSS	DO	SVI	FLOW	SS
DATE	MGD	MG/L	TONS	MG/L	MG/L	TONS	MGD	%	MG/L	MG/L	C	MG/L	MG/L	MG/L		MGD	TONS
9/ 1	8.6	82	2.9	84	135	4.8	3.7	43	10400	8400	22	2880	2320	1.0	142	0.023	1.0
9/ 2	8.3	70	2.4	90	132	4.6	3.7	45	9120	7360	22	2770	2240	1.2	177	0.051	1.9
9/ 3	8.6	77	2.6	94	122	4.4	3.3	38	9520	8000	23	2490	2020	0.6	193	0.067	2.7
9/ 4	8.2	63	2.2	82	103	3.5	3.2	39	8880	7460	23	2380	1960	0.5	272	0.041	1.5
9/ 5	7.7	68	2.2	61	90	2.9	3.0	39	8520	7080	23	2300	1890	0.3	227	0.024	0.9
9/ 6	8.1	67	2.3	68	111	3.7	3.1	38	-1	-1	23	2400	1960	0.4	239	0.016	-1.0
9/ 7	8.7	73	2.6	88	124	4.5	3.2	37	9760	8160	23	2230	1810	0.5	249	0.006	0.2
9/ 8	7.9	74	2.4	84	129	4.2	3.5	44	7000	6000	22	2270	1910	0.4	231	0.000	0.0
9/ 9	6.8	90	2.6	94	149	4.2	3.6	53	7360	6200	22	2510	2080	0.3	258	0.000	0.0
9/10	6.2	99	2.6	92	140	3.6	3.2	52	7200	6080	22	2620	2190	0.5	238	0.000	0.0
9/11	6.2	91	2.4	76	112	2.9	3.2	52	6640	5600	23	2930	2490	0.2	258	0.022	0.6
9/12	6.1	75	1.9	70	101	2.6	3.2	52	6840	5960	23	2990	2550	0.5	258	0.052	1.5
9/13	6.3	85	2.2	82	100	2.6	3.2	51	6120	5280	24	3390	2800	0.7	230	0.040	1.0
9/14	6.1	92	2.3	80	116	3.0	3.2	52	5920	5080	23	2860	2350	0.6	226	0.041	1.0
9/15	6.1	85	2.2	88	122	3.1	3.2	52	7530	6400	22	2640	2170	0.4	240	0.042	1.3
9/16	6.1	76	1.9	98	133	3.4	3.2	52	7470	6340	23	2620	2170	0.5	226	0.044	1.4
9/17	6.1	79	2.0	86	123	3.1	3.1	51	7030	5900	21	2540	2120	0.9	250	0.056	1.6
9/18	5.8	82	2.0	82	106	2.6	3.1	53	3280	-1	21	2100	1680	1.0	280	0.038	0.5
9/19	5.8	92	2.2	74	111	2.7	3.5	60	6040	5200	21	2390	1970	1.1	300	0.035	0.9
9/20	5.7	136	3.2	100	140	3.3	3.2	56	7920	6720	21	2690	2270	1.3	266	0.031	1.0
9/21	5.1	89	1.9	92	136	2.9	2.9	57	7300	6230	21	2920	2390	1.1	272	0.046	1.4
9/22	4.7	81	1.6	96	123	2.4	3.3	70	7070	5970	22	3030	2450	1.4	247	0.053	1.6
9/23	3.8	93	1.5	96	137	2.2	3.2	84	6630	5560	23	3440	2820	1.1	229	0.050	1.4
9/24	3.5	90	1.3	92	138	2.0	3.2	91	7230	6060	23	3520	2860	1.3	255	0.052	1.6
9/25	3.6	91	1.4	86	106	1.6	3.4	94	6930	5830	23	3580	2920	1.4	264	0.052	1.5
9/26	3.6	72	1.1	80	88	1.3	3.2	89	6670	5700	23	3400	2780	1.3	241	0.049	1.4
9/27	3.6	114	1.7	82	106	1.6	3.1	86	6800	5530	21	3520	2830	3.8	261	0.047	1.3
9/28	2.9	82	1.0	76	105	1.3	3.1	107	5570	4770	22	4030	3290	7.0	234	0.035	0.8
TOTAL	170.2		58.7			85.0	91.0									1.614	30.1
AVER.	6.1	85	2.1	85	119	3.0	3.2	59	7287	6264	22	2837	2332	1.1	242	0.036	1.1

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/17/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: SEPTEMBER 1976

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M							BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
9/ 1	109.6	1.26	0.76	0.86	1.54	714	15.64	22.36	3.7	7.94	12.04	19.98	13.3	14	0.5	18	15	0.5	83	89
9/ 2	103.4	1.46	0.74	0.35	0.96	689	14.51	20.98	5.0	7.64	13.27	20.91	7.2	28	1.0	22	17	0.6	60	87
9/ 3	99.0	1.42	0.79	0.58	1.45	714	13.52	18.71	5.0	6.86	13.85	20.72	4.3	59	2.1	40	34	1.2	23	72
9/ 4	79.7	1.87	0.65	0.17	1.03	681	12.32	17.13	5.2	6.56	13.33	19.89	5.9	55	1.9	36	30	1.0	13	71
9/ 5	65.4	2.10	0.55	-0.16	0.84	639	11.18	15.54	5.4	6.34	13.18	19.52	8.9	42	1.3	26	22	0.7	38	76
9/ 6	84.9	1.41	0.69	-1.00	-1.00	672	12.27	16.97	5.7	6.62	-1.00	-1.00	-1.0	59	2.0	30	28	0.9	12	75
9/ 7	101.8	2.24	0.90	-1.00	-1.00	722	12.25	16.75	6.1	6.15	16.66	22.80	5.5	107	3.9	56	68	2.5	-46	45
9/ 8	96.2	1.51	0.81	-1.14	-0.37	656	11.32	16.34	7.1	6.26	13.55	19.80	10.9	55	1.8	38	33	1.1	26	74
9/ 9	95.6	1.32	0.74	-0.20	0.52	565	10.77	16.48	6.8	6.92	13.74	20.66	20.6	35	1.0	27	23	0.7	61	85
9/10	81.9	1.34	0.60	-1.12	-0.37	515	10.25	15.55	5.9	7.22	11.96	19.18	99.4	7	0.2	18	7	0.2	93	95
9/11	65.5	1.65	0.42	-0.99	-0.12	515	11.47	17.39	5.2	8.08	9.97	18.04	22.1	8	0.2	13	8	0.2	91	93
9/12	58.2	2.01	0.37	-0.19	0.65	506	11.51	17.55	4.8	8.24	9.64	17.88	10.9	6	0.2	14	12	0.3	92	88
9/13	59.5	2.79	0.34	-0.26	1.13	523	13.48	20.33	4.7	9.34	8.49	17.83	9.6	32	0.8	18	39	1.0	62	61
9/14	66.8	1.75	0.46	-0.90	-0.06	506	11.01	16.79	4.8	7.88	8.34	16.23	11.2	17	0.4	18	7	0.2	82	94
9/15	70.2	1.65	0.52	1.08	1.84	506	10.17	15.50	6.0	7.28	12.68	19.96	12.9	9	0.2	13	9	0.2	89	93
9/16	76.6	1.46	0.57	0.33	0.97	506	10.09	15.38	6.6	7.22	13.60	20.83	10.2	26	0.7	22	16	0.4	66	88
9/17	70.8	1.70	0.54	-0.60	0.15	506	9.78	14.75	6.0	7.00	11.84	18.84	7.9	29	0.7	25	17	0.4	63	86
9/18	58.0	1.85	0.55	-3.65	-2.82	482	7.69	11.00	6.1	5.79	5.60	11.39	16.5	7	0.2	16	7	0.2	91	93
9/19	60.8	1.88	0.49	2.33	3.29	482	8.75	14.03	6.6	6.59	11.00	17.59	12.2	23	0.6	18	15	0.4	75	86
9/20	75.3	1.53	0.53	0.44	1.49	473	9.68	15.11	6.1	7.41	13.52	20.93	16.9	9	0.2	18	11	0.3	93	92
9/21	65.5	1.67	0.44	-0.46	0.26	423	9.40	14.75	5.7	8.05	11.79	19.84	11.1	18	0.4	19	13	0.3	80	90
9/22	54.6	2.23	0.36	0.59	1.37	390	8.99	15.30	6.2	8.35	12.23	20.58	10.0	25	0.5	23	19	0.4	69	85
9/23	49.1	2.02	0.28	-1.63	-0.89	315	8.25	15.20	3.8	9.48	7.83	17.31	11.5	8	0.1	15	12	0.2	91	91
9/24	45.6	2.19	0.26	0.28	1.00	291	7.78	14.89	3.3	9.70	7.71	17.41	10.2	10	0.1	17	14	0.2	89	90
9/25	36.0	2.80	0.20	-0.36	0.63	299	8.14	15.82	2.9	9.87	6.76	16.62	10.1	10	0.2	16	14	0.2	89	87
9/26	29.9	3.15	0.17	-1.01	-0.04	299	7.73	14.60	2.4	9.37	5.74	15.11	10.3	7	0.1	19	14	0.2	90	84
9/27	36.0	2.27	0.20	0.46	1.68	299	8.00	14.69	2.7	9.70	6.32	16.02	11.1	7	0.1	12	13	0.2	94	88
9/28	28.7	2.67	0.14	-1.66	-0.77	241	7.38	15.26	1.1	11.11	3.14	14.25	15.5	9	0.1	14	13	0.2	89	88
TOTAL										218.97	287.77	500.12			21.5			14.8		
AVER.	68.7	1.90	0.50	-0.26	0.59	505	10.48	16.29	5.0	7.82	10.66	18.52	14.7	26	0.8	22	19	0.5	66	84

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/17/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: OCTOBER 1976

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
10/ 7	4.2	94	1.6	96	130	2.3	3.3	79	5230	4200	22	1830	1420	3.1	106	0.000	0.0
10/ 8	5.1	104	2.2	97	125	2.7	3.2	63	6170	5340	22	2460	2040	4.3	106	0.000	0.0
10/ 9	6.2	102	2.6	82	94	2.4	3.2	52	7640	6080	22	2690	2130	2.7	256	0.000	0.0
10/10	5.6	84	2.0	70	99	2.3	3.2	57	8000	6440	21	3060	2390	2.2	142	0.000	0.0
10/11	5.5	95	2.2	104	116	2.7	3.2	58	6920	5680	22	3050	2480	2.5	120	0.000	0.0
10/12	6.1	101	2.6	92	121	3.1	3.2	52	8320	6720	22	3130	2480	3.0	133	0.014	0.5
10/13	6.1	89	2.3	89	135	3.4	3.2	52	7440	5840	22	3100	2450	2.7	175	0.027	0.8
10/14	6.1	95	2.4	94	132	3.4	3.2	52	7720	6200	22	2990	2410	2.9	200	0.032	1.0
10/15	6.1	94	2.4	99	137	3.5	3.2	52	7640	6080	21	3170	2530	2.8	194	0.035	1.1
10/16	6.1	84	2.1	86	105	2.7	3.3	54	8000	6440	21	3030	2360	2.2	289	0.038	1.3
10/17	6.0	123	3.1	92	146	3.7	3.2	53	7600	6040	22	2890	2350	2.6	272	0.044	1.4
10/18	6.1	116	3.0	106	135	3.4	3.5	57	7120	5880	21	2980	2410	3.0	222	0.046	1.4
10/19	6.0	100	2.5	101	137	3.4	3.7	62	7000	5800	21	2960	2450	2.7	254	0.053	1.5
10/20	6.0	92	2.3	94	158	4.0	3.7	62	7000	5800	21	2990	2460	3.5	275	0.060	1.8
10/21	6.1	105	2.7	94	136	3.5	3.7	61	7480	6040	21	2940	2310	4.1	244	0.059	1.8
10/22	6.0	80	2.0	96	136	3.4	3.7	62	7320	6080	21	3080	2500	5.0	214	0.067	2.0
10/23	5.6	89	2.1	92	134	3.1	3.7	66	6630	5600	19	2730	2180	3.6	296	0.076	2.5
10/24	5.5	76	1.7	77	104	2.4	3.6	65	7170	5900	18	2880	2350	5.1	197	0.075	2.2
10/25	5.7	80	1.9	84	127	3.0	3.8	67	7330	6000	19	3030	2500	4.4	178	0.054	1.7
10/26	5.5	97	2.2	110	152	3.5	3.5	64	7320	6200	18	2640	2150	3.8	187	0.081	2.5
10/27	5.7	89	2.1	101	161	3.8	3.5	61	6800	5680	19	2610	2120	4.3	253	0.043	1.2
10/28	5.7	89	2.1	90	156	3.7	3.7	65	7080	5760	19	2720	2190	5.2	222	0.023	0.7
10/29	5.4	85	1.9	102	126	2.8	3.4	63	7000	5770	19	2830	2300	6.1	222	0.064	1.9
10/30	5.7	82	1.9	94	124	2.9	3.6	63	6770	5440	19	2830	2320	6.0	282	0.062	1.8
10/31	5.8	73	1.8	77	104	2.5	4.0	69	6630	5500	20	3070	2460	5.7	212	0.049	1.4
TOTAL	143.9		55.7			77.5	86.5									1.003	30.5
AVER.	5.8	93	2.2	93	129	3.1	3.5	60	7229	5860	21	2868	2310	3.7	210	0.040	1.2

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/17/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: OCTOBER 1976

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M							BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
10/ 7	51.5	1.56	0.58	-0.66	0.12	349	4.85	8.66	0.3	5.04	1.99	7.03	28.2	14	0.2	20	9	0.2	85	93
10/ 8	60.2	1.61	0,47	0.02	0.91	423	7.92	12.89	0.2	6.78	2.21	8.99	29.7	14	0.3	16	9	0.2	87	93
10/ 9	55.0	1.89	0.41	-0.18	1.03	515	10.53	15.96	0.6	7.41	3.43	10.85	27.9	15	0.4	20	10	0.3	85	89
10/10	52.3	2.22	0.35	-0.28	0.65	465	10.82	17.00	0.5	8.43	3.41	11.84	31.5	16	0.4	18	9	0.2	81	91
10/11	60.2	1.78	0.39	-1.07	-0.18	457	10.59	16.75	0.3	8.41	2.63	11.04	29.9	16	0,4	20	10	0,2	83	91
10/12	69.7	1.50	0.45	-0.26	0.68	506	12.05	18.38	0.4	8.63	3.36	11.98	13.1	17	0.4	20	14	0.4	83	88
10/13	77.7	1.40	0.51	-0.11	0.60	506	11.94	18.20	1.1	8.54	4.19	12.74	10.9	13	0.3	16	10	0.3	85	93
10/14	76.0	1,47	0.51	-0.27	0.51	506	11.51	17.55	1.1	8,24	4.35	12.59	7.3	27	0.7	19	10	0.3	72	92
10/15	78.9	1.45	0.50	0.42	1.15	506	12.21	18.61	2.2	8.74	6.23	14.96	10.7	11	0.3	17	8	0.2	88	94
10/16	60.5	1.56	0.41	0.31	1.17	506	11.67	17.98	3.0	8.35	7.98	16.33	10.7	10	0.3	20	8	0.2	88	92
10/17	82.7	-1.00	0.56	-1.00	-1.00	498	10.95	16.78	2.5	7.97	6.72	14.68	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
10/18	77.7	1.39	0.52	0.09	0.99	506	11.48	18.06	3.6	8.21	8.08	16.30	10.1	10	0.3	16	6	0.2	91	96
10/19	77.6	1.38	0.51	-0.64	0.12	498	11.21	18.13	2 9	8.16	6.83	14.98	8.8	6	0.2	17	5	0.1	94	96
10/20	89.5	1.22	0.58	0.29	0.89	498	11.33	18.31	3.8	8.24	8.27	16.51	8.8	5	0.1	14	6	0.2	95	96
10/21	78.3	1.40	0.54	0.01	0.82	506	11.32	18.19	4.0	8.10	9.17	17.28	8.9	4	0.1	16	6	0.2	96	96
10/22	77.0	1.53	0.49	0.73	1.35	498	11.67	18.86	5.2	8.49	10.99	19.48	9.1	4	0.1	16	7	0.2	95	95
10/23	70.8	1.61	0.52	-0.08	0.61	465	9.65	16.03	4.7	7.52	11.13	18.66	7.0	5	0.1	13	5	0.1	94	96
10/24	54.0	1.98	0.37	0.07	0.84	457	10.00	16.54	4.9	7.94	10.27	18.21	7.7	5	0.1	12	5	0.1	93	95
10/25	68.3	1.86	0.44	0.79	1.48	473	10.90	18.17	5.8	8.35	12.01	20.36	10.4	13	0.3	17	10	0.2	84	92
10/26	78.9	1.82	0.59	0.89	1.79	457	9.17	15.00	6.0	7.28	12.33	19.60	3.8	118	2.7	48	44	1.0	-21	71
10/27	86.6	1.18	0.65	-0.60	-3.02	473	9.39	15.16	5.7	7.19	10.98	18.18	13.3	6	0.1	14	8	0.2	93	95
10/28	83.9	-1.00	0.61	-1.00	-1.00	473	9.79	16.14	5.0	7.50	10.30	17.80	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
10/29	64.2	1.70	0.45	-1.50	-0.78	448	9.65	15.72	2.2	7.80	5.70	13.51	6.0	17	0.4	18	9	0.2	80	93
10/30	66.7	1.61	0.46	0.30	0.99	473	10.18	16.61	2.9	7.80	6.60	14.40	7.6	6	0.1	15	5	0.1	93	96
10/31	56.9	1.88	0.37	0.66	1.39	482	11.24	18.99	3.8	8.46	7.83	16.29	11.0	5	0.1	16	4	0.1	93	96
TOTAL										197.60	176.99	374.59			8.4			5.2		
AVER.	70.2	1.61	0.49	-0.05	0.74	478	10.48	16.75	2.9	7.90	7.08	14.98	13.6	16	0.4	18	9	0.2	83	93

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: NOVEMBER 1976

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY	INFLUENT********					****RETURN	SOLIDS****			*******MIXED	LIQUOR********				***WASTE***	
	FLOW	SS	SS	TOC	BOD	BOD	FLOW		SS	VSS	TEMP	SS	VSS	DO	SVI	FLOW	SS
DATE	MGD	MG/L	TONS	MG/L	MG/L	TONS	MGD	%	MG/L	MG/L	C	MG/L	MG/L	MG/L		MGD	TONS
11/ 1	5.6	132	3.1	116	130	3.0	3.9	70	6230	5330	21	2840	2340	5.1	170	0.061	1.6
11/ 2	5.1	101	2.1	100	136	2.9	3.9	76	6320	5240	20	2710	2260	4.6	192	0.073	1.9
11/ 3	5.6	206	4.8	155	192	4.5	3.9	70	6480	5400	20	2770	2370	4.6	241	0.079	2.1
11/ 4	5.3	90	2.0	94	146	3.2	4.1	77	6160	5120	20	2980	2460	3.4	183	0.077	2.0
11/ 5	4.8	84	1.7	91	111	2.2	4.2	87	6760	5640	20	3000	2470	4.7	234	0.091	2.6
11/ 6	5.6	87	2.0	92	114	2.7	4.1	73	7330	5930	20	2970	2450	2.7	242	0.086	2.6
11/ 7	4.6	84	1.7	91	103	2.1	3.1	65	6160	4920	20	2520	2100	2.8	278	0.069	1.8
11/ 8	5.5	95	2.2	96	99	2.3	3.4	62	6400	5440	19	2430	1970	3.7	194	0.065	1.7
11/ 9	5.4	88	2.0	85	131	2.9	4.5	83	5480	4560	20	2660	2180	4.1	226	0.070	1.6
11/10	5.5	-1	-1.0	93	127	2.9	4.4	80	4360	3600	20	2360	1900	3.9	234	0.056	1.2
11/11	6.5	83	2.2	86	131	3.6	3.8	58	6030	4900	19	2480	2030	3.5	276	0.035	0.9
11/12	6.1	85	2.2	96	135	3.4	3.2	52	6020	4890	19	2570	2100	4.6	289	0.036	0.9
11/13	6.1	80	2.0	80	130	3.3	3.2	52	5920	5240	19	2600	2320	4.7	325	0.053	1.3
11/14	6.0	92	2.3	92	105	2.6	3.2	53	6780	5640	19	2330	1970	4.5	280	0.062	1.8
11/15	5.9	83	2.0	93	127	3.1	3.2	54	6630	5530	19	3150	2610	4.0	320	0.039	1.1
11/16	5.8	88	2.1	94	134	3.2	3.2	55	4720	3960	20	2110	1760	4.3	332	0.051	1.0
11/17	6.1	92	2.3	98	126	3.2	3.7	61	5200	4280	20	2200	1760	4.6	310	0.067	1.5
11/18	6.8	105	3.0	112	148	4.2	4.5	66	5530	4530	19	2350	1940	6.0	332	0.038	0.9
11/19	7.0	90	2.6	94	131	3.8	4.7	67	4400	3930	19	2060	1710	4.7	390	-1.000	-1.0
11/20	6.9	53	1.5	72	99	2.8	4.7	68	5130	4260	19	2170	1840	4.9	352	-1.000	-1.0
11/21	7.2	97	2.9	99	130	3.9	4.7	65	4560	3920	19	1750	1490	5.1	428	-1.000	-1.0
TOTAL	123.6		46.9			66.0	81.6									1.108	28.2
AVER.	5.9	96	2.3	97	128	3.1	3.9	67	5832	4870	20	2524	2097	4.3	278	0.062	1.6

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: NOVEMBER 1976

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M							BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
11/ 1	68.7	1.72	0.47	-0.47	0.57	465	10.04	17.03	4.6	7.83	8.50	16.32	9.9	3	0.1	14	3	0.1	98	98
11/ 2	65.5	1.64	0.46	-0.32	0.47	423	8.73	15.40	4.2	7.47	8.04	15.51	7.4	8	0.2	16	8	0.2	92	94
11/ 3	101.5	0.99	0.69	-0.36	0.75	465	9.79	16.61	4.6	7.64	8.84	16.47	7.2	6	0.1	15	7	0.2	97	96
11/ 4	73.0	1.52	0.48	0.98	1.64	440	9.97	17.68	6.5	8.21	11.08	19.29	9.1	6	0.1	15	10	0.2	93	93
11/ 5	50.3	2.08	0.33	0.59	1.38	399	9.09	17.64	5.9	8.27	11.23	19.50	7.2	8	0.2	16	5	0.1	90	95
11/ 6	60.3	1.74	0.39	-0.34	0.45	465	10.50	18.19	4.4	8.19	9.66	17.85	6.3	8	0.2	16	4	0.1	91	96
11/ 7	46.7	2.07	0.36	-0.81	0.05	399	7.64	12.57	5.1	6.95	9.11	16.05	8.5	6	0.1	15	5	0.1	93	95
11/ 8	51.4	2.27	0.42	-1.00	-1.00	457	8.44	13.65	5.0	6.70	9.31	16.01	-1.0	-1	-1.0	23	12	0.3	-1	68
11/ 9	66.8	1.72	0.49	-0.52	0.17	448	9.07	16.62	4.6	7.33	7.47	14.81	8.8	4	0.1	14	4	0.1	95	97
11/10	65.9	1.70	0.56	-1.00	0.97	457	8.19	14.75	7.1	6.51	8.44	14.94	6.8	52	1.2	30	21	0.5	-1	83
11/11	80.4	1.31	0.63	0.91	1.64	540	10.18	16.13	6.9	6.84	11.39	18.23	10.3	33	0.9	20	17	0.5	60	87
11/12	77.7	1.21	0.59	-0.36	0.31	506	9.90	15.09	6.5	7.08	10.83	17.91	13.4	17	0.4	19	8	0.2	63	94
11/13	74.8	1.25	0.52	-0.02	0.66	506	10.01	15.26	6.6	7.17	10.78	17.95	9.2	25	0.6	21	12	0.3	69	91
11/14	59.5	1.59	0.48	0.16	1.13	498	8.83	13.53	6.3	6.42	11.88	18.30	7.9	23	0.6	24	10	0.3	75	90
11/15	70.7	1.32	0.43	-0.14	0.53	490	11.73	18.16	5.3	8.68	10.10	18.79	16.7	2	0.0	10	4	0.1	98	97
11/16	73.4	1.22	0.67	-2.03	-1.35	482	7.73	11.99	5.7	5.82	7.62	13.44	11.7	6	0.1	19	5	0.1	93	96
11/17	72.5	1.46	0.66	1.01	1.90	506	8.47	13.61	6.7	6.06	9.59	15.65	5.6	52	1.3	42	23	0.6	43	62
11/18	95.0	1.85	0.78	3.06	4.41	565	10.09	16.76	7.5	6.48	11.21	17.69	2.3	241	6.8	102	70	2.0	-129	53
11/19	86.6	1.58	0.81	-1.00	-1.00	581	9.10	15.22	7.4	5.68	8.82	14.50	-1.0	107	3.1	46	35	1.0	-18	73
11/20	64.5	3.85	0.56	-1.00	-1.00	573	9.45	15.89	7.0	5.98	9.81	15.79	-1.0	178	5.1	67	58	1.7	-235	41
11/21	88.3	1.54	0.95	-1.00	-1.00	598	7.95	13.15	7.1	4.82	8.83	13.65	-1.0	168	5.0	64	54	1.6	-72	58
TOTAL										146.11	202.53	348.65			26.4			10.1		
AVER.	71.1	1.70	0.56	0.08	0.92	489	9.28	15.44	6.0	6.96	9.64	16.60	8.7	48	1.3	29	18	0.5	43	86

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: DECEMBER 1976

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
	FLOW	SS	SS	TOC	BOD	BOD	FLOW		SS	VSS	TEMP	SS	VSS	DO	SVI	FLOW	SS
DATE	MGD	MG/L	TONS	MG/L	MG/L	TONS	MGD	%	MG/L	MG/L	C	MG/L	MG/L	MG/L		MGD	TONS
12/26	5.9	98	2.4	92	111	2.7	4.1	69	6400	5360	18	2530	2080	3.8	189	0.0	0.0
12/27	6.7	85	2.4	113	143	4.0	4.2	63	6840	5640	19	2770	2250	2.5	188	0.0	0.0
12/28	7.0	86	2.5	113	160	4.7	4.0	57	9200	7770	18	3010	2430	2.8	193	0.0	0.0
12/29	7.4	86	2.7	111	175	5.4	4.2	57	7900	6600	18	3100	2520	3.0	163	0.017	0.6
12/30	7.7	103	3.3	130	174	5.6	4.2	55	-1	-1	17	2970	2440	3.4	199	0.052	-1.0
12/31	7.4	114	3.5	119	179	5.5	4.2	57	7720	6080	16	2890	2400	2.3	190	0.010	0.3
TOTAL	42.1		16.8			27.9	24.9									0.079	0.9
AVER.	7.0	95	2.8	113	157	4.7	4.1	60	7612	6290	18	2878	2353	3.0	187	0.013	0.2

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77. METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: DECEMBER 1976

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M							BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
12/26	61.8	1.84	0.48	-0.72	0.28	490	9.42	15.97	1.2	6.97	3.75	10.73	16.1	27	0.7	20	13	0.3	72	88
12/27	90.4	1.34	0.64	-0.12	0.54	556	11.72	19.06	1.5	7.64	4.48	12.11	21.7	20	0.6	22	13	0.4	76	91
12/28	105.7	1.25	0.70	0.77	1.35	581	13.30	20.90	3.0	8.30	9.18	17.48	37.4	16	0.5	23	12	0.4	81	92
12/29	122.2	1.75	0.78	1.55	2.44	614	14.46	22.70	5.0	8.54	11.50	20.04	4.2	135	4.2	69	78	2.4	-56	55
12/30	126.5	1.70	0.83	-1.00	-1.00	639	14.44	22.31	6.6	8.19	-1.00	-1.00	-1.0	143	4.6	74	77	2.5	-38	56
12/31	125.0	1.44	0.83	-1.00	-1.00	614	13.50	21.16	4.4	7.97	10.18	18.14	4.7	115	3.5	48	51	1.6	0	72
TOTAL										47.60	39.08	78.50			14.0			7.5		
AVER.	105.3	1.55	0.71	0.37	1.15	583	12.81	20.35	3.6	7.93	7.82	15.70	16.8	76	2.3	43	41	1.2	22	76

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JANUARY 1977

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
1/ 1	6.7	83	2.3	84	124	3.5	4.3	64	-1	-1	17	3130	2580	2.4	231	0.0	-1.0
1/ 2	6.7	82	2.3	82	104	2.9	4.3	64	-1	-1	17	3000	2420	2.2	220	0.0	-1.0
1/ 3	6.7	94	2.6	108	150	4.2	4.3	64	7800	6320	17	2780	2230	2.2	207	0.0	0.0
1/ 4	7.3	200	6.1	156	199	6.1	4.3	59	7200	6100	17	2890	2380	1.8	214	0.037	1.1
1/ 5	8.5	145	5.1	137	205	7.3	4.3	51	7000	5960	17	2630	2140	2.1	193	0.021	0.6
1/ 6	7.3	188	5.7	144	184	5.6	3.9	53	7640	6320	17	2840	2340	3.0	196	0.042	1.3
1/ 7	7.6	115	3.6	128	164	5.2	4.1	54	7160	5960	16	2640	2150	2.6	218	-0.060	1.8
1/ 8	7.2	-1	-1.0	-1	-1	-1.0	4.2	58	-1	-1	16	2770	2220	2.2	222	0.057	-1.0
1/ 9	6.4	98	2.6	110	124	3.3	4.1	64	6520	5960	15	2890	2550	2.4	225	0.058	1.6
1/10	6.7	132	3.7	146	174	4.9	4.2	63	5920	5560	15	2550	2180	3.2	267	0.068	1.7
1/11	6.7	152	4.2	140	162	4.5	4.1	61	6160	5560	15	2450	2100	3.1	269	0.069	1.8
1/12	6.8	107	3.0	130	206	5.8	3.8	56	6720	5680	17	2590	2230	1.5	207	0.065	1.8
1/13	6.8	125	3.5	130	153	4.3	3.9	57	7000	5960	17	2630	2160	3.3	-1	0.069	2.0
1/14	6.2	130	3.4	122	169	4.4	4.4	71	6680	5640	16	2540	2120	2.8	187	0.068	1.9
1/15	5.4	93	2.1	113	161	3.6	4.6	85	5830	4800	16	2820	2320	2.4	-1	0.063	1.5
1/16	4.8	90	1.8	110	137	2.7	4.2	87	4730	4300	16	2720	2250	3.5	204	0.076	1.5
1/17	5.2	92	2.0	108	160	3.5	4.3	83	4870	3940	15	2680	2160	3.7	247	0.104	2.1
1/18	5.2	100	2.2	122	172	3.7	4.7	90	4900	4060	15	2600	2140	3.4	247	0.105	2.1
1/19	3.4	102	1.4	109	177	2.5	3.3	97	4960	4100	17	2640	2180	3.0	-1	0.061	1.3
1/21	3.3	95	1.3	146	172	2.4	3.0	91	4930	4100	15	2730	2230	4.6	-1	0.0	0.0
1/22	5.5	93	2.1	121	162	3.7	4.6	84	5970	4900	16	2860	2320	3.9	164	0.0	0.0
1/23	5.9	79	1.9	87	126	3.1	4.9	83	5760	4820	16	2380	2350	3.6	212	0.054	1.3
1/24	6.3	98	2.6	114	155	4.1	4.8	76	6020	5080	17	2760	2270	3.4	197	0.089	2.2
1/25	6.3	101	2.7	124	184	4.8	4.7	75	6180	5040	15	2700	2210	4.0	201	0.109	2.8
1/26	6.8	91	2.6	115	150	4.3	4.3	63	6500	5460	15	2700	2240	3.6	185	0.108	2.9
1/27	6.6	143	3.9	152	191	5.3	4.3	65	6900	5770	15	2840	2430	3.4	198	0.089	2.6
1/28	6.5	106	2.9	124	188	5.1	4.4	68	6900	5930	15	3180	2630	3.6	196	0.092	2.6
1/29	6.1	102	2.6	101	133	3.4	4.4	72	6900	5670	15	3430	2810	4.0	200	0.078	2.2
1/30	5.6	81	1.9	84	117	2.7	4.5	80	6470	5470	15	3090	2510	3.7	223	0.086	2.3
1/31	5.9	92	2.3	108	152	3.7	4.5	76	6470	5200	16	3450	2810	3.6	218	0.099	2.7
TOTAL	186.4		84.6			120.6	127.7									1.827	45.9
AVER.	6.2	111	2.9	119	161	4.2	4.3	71	6300	5321	16	2814	2322	3.1	213	0.061	1.7

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JANUARY 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M							BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	BIOSYNTHESIS GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	FLUX #/SF/DAY Q+R	DOB FT	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
1/ 1	78.4	-1.00	0.49	-1.00	-1.00	556	13.24	21.74	5.5	8.63	-1.00	-1.00	-1.0	144	4.0	68	70	2.0	-72	44
1/ 2	65.8	-1.00	0.44	-1.00	-1.00	556	12.69	20.83	6.8	8.27	-1.00	-1.00	-1.0	158	4.4	75	75	2.1	-92	28
1/ 3	94.9	2.12	0.68	-1.00	-1.00	556	11.76	19.30	7.0	7.66	14.92	22.58	7.8	104	2.9	50	55	1.5	-10	63
1/ 4	137.1	1.41	0.92	-0.25	1.51	606	13.32	21.16	6.8	7.97	13.44	21.41	3.3	174	5.3	91	85	2.6	13	57
1/ 5	164.5	0.91	1.23	-0.41	0.55	706	14.11	21.25	7.0	7.25	13.39	20.64	5.5	88	3.1	52	54	1.9	39	74
1/ 6	126.8	1.40	0.87	0.53	2.21	606	13.09	20.08	7.0	7.83	14.61	22.44	3.9	144	4.4	70	72	2.2	23	61
1/ 7	117.6	1.37	0.88	-0.34	0.60	631	12.67	19.50	6.6	7.28	13.04	20.32	4.6	84	2.7	50	42	1.3	27	74
1/ 8	-1.0	-1.00	-1.00	-1.00	-1.00	598	12.59	19.93	-1.0	7.64	-1.00	-1.00	-1.0	106	3.2	62	38	1.1	-1	-1
1/ 9	74.9	2.85	0.47	-1.00	-1.00	531	11.68	19.16	6.3	7.97	11.43	19.39	3.5	147	3.9	72	74	2.0	-49	40
1/10	110.0	1.21	0.81	-0.43	0.62	556	10.79	17.55	6.3	7.03	10.37	17.40	4.2	89	2.5	58	48	1.3	33	72
1/11	102.4	1.38	0.78	0.52	2.03	556	10.36	16.70	7.0	6.75	11.78	18.53	4.0	101	2.8	60	61	1.7	34	62
1/12	132.2	1.10	0.95	0.91	1.67	565	11.12	17.33	7.2	7.14	13.16	20.30	4.2	108	3.1	58	66	1.9	0	66
1/13	98.2	2.52	0.73	1.89	3.76	565	11.29	17.77	7.0	7.25	13.39	20.64	3.0	169	4.8	79	86	2.4	-34	44
1/14	98.9	1.61	0.75	0.18	1.33	515	9.94	17.00	7.2	7.00	13.08	20.08	4.5	98	2.5	56	56	1.4	25	67
1/15	82.1	1.77	0.57	0.35	1.32	448	9.61	17.80	6.7	7.77	10.75	18.52	4.2	128	2.9	66	65	1.5	-37	68
1/16	62.1	1.89	0.44	-0.85	0.12	399	8.24	15.45	6.1	7.50	8.07	15.57	4.9	84	1.7	45	44	0.9	7	68
1/17	78.5	1.77	0.58	0.85	1.76	432	8.80	16.07	5.4	7.39	7.53	14.92	3.3	113	2.4	51	59	1.3	-19	63
1/18	84.4	1.20	0.63	0.17	0.83	432	8.54	16.25	5.5	7.17	7.69	14.86	5.3	30	0.7	28	20	0.4	70	88
1/19	56.8	-1.00	0.42	-0.53	0.16	282	5.67	11.17	3.8	7.28	5.86	13.13	6.4	56	0.8	34	30	0.4	45	83
1/21	53.6	1.47	0.39	-2.35	-1.75	274	5.69	10.86	0.0	7.52	1.54	9.06	34.7	19	0.3	26	14	0.2	80	92
1/22	84.1	1.16	0.58	-0.20	0.41	457	9.93	18.24	0.3	7.88	2.27	10.15	29.5	15	0.3	21	11	0.3	84	93
1/23	70.2	1.45	0.48	0.70	1.38	490	10.73	19.64	2.1	7.94	4.56	12.50	7.9	12	0.3	14	10	0.2	85	92
1/24	92.2	1.09	0.65	0.32	1.00	523	10.98	19.34	3.1	7.61	6.15	13.75	5.4	12	0.3	18	10	0.3	88	94
1/25	109.4	0.98	0.79	0.83	1.42	523	10.74	18.75	5.4	7.44	9.56	17.00	5.4	13	0.3	23	12	0.3	87	93
1/26	96.3	1.21	0.69	-0.32	0.35	565	11.59	18.92	3.8	7.44	7.68	15.12	4.7	11	0.3	14	14	0.4	88	91
1/27	119.0	1.02	0.78	0.09	0.96	548	11.83	19.54	3.8	7.83	8.15	15.98	4.6	33	0.9	32	28	0.8	77	85
1/28	115.3	1.09	0.70	1.00	1.68	540	13.05	21.88	5.2	8.77	10.36	19.12	4.8	50	1.4	37	31	0.8	53	84
1/29	76.6	1.61	0.44	1.12	2.08	506	13.21	22.74	6.0	9.45	11.62	21.07	5.7	56	1.4	38	27	0.7	45	80
1/30	61.8	1.71	0.39	-0.13	0.65	465	10.92	19.70	5.9	8.52	10.75	19.26	5.7	46	1.1	18	13	0.3	43	89
1/31	84.6	-1.00	0.48	0.39	1.02	490	12.85	22.65	5.7	9.51	10.45	19.96	6.8	11	0.3	16	7	0.2	88	95
TOTAL										232.66	265.58	473.71			64.9			34.5		
AVER.	94.1	1.49	0.66	0.16	1.11	516	11.03	18.61	4.7	7.76	9.84	17.54	7.0	80	2.2	46	43	1.1	28	73

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: MARCH 1977

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
3/ 8	5.1	146	3.1	142	198	4.2	5.2	102	7240	5960	16	3650	2970	-1.0	-1	0.0	0.0
3/ 9	5.5	151	3.5	167	208	4.8	5.7	104	7760	6400	16	3640	3030	-1.0	103	0.011	0.4
3/10	5.9	125	3.1	140	209	5.1	5.6	95	7300	5930	16	3780	3020	4.5	105	0.019	0.6
3/11	6.0	139	3.5	142	193	4.8	6.0	100	6840	5560	14	4020	3310	3.3	118	0.014	0.4
3/12	5.9	96	2.4	118	151	3.7	5.9	100	8280	6760	14	4780	3820	3.5	109	0.032	1.1
3/13	6.2	90	2.3	86	123	3.2	6.0	97	7320	5720	15	4000	3110	5.0	123	0.061	1.9
3/14	6.2	104	2.7	108	172	4.4	5.8	94	6000	4680	16	3190	2470	1.9	127	0.098	2.5
3/15	6.3	111	2.9	124	163	4.8	5.9	94	5640	4520	16	3230	2600	3.3	173	0.134	3.2
3/16	6.1	115	2.9	122	195	5.0	6.0	98	7030	5760	15	3460	2770	3.5	151	0.183	5.4
3/17	6.1	103	2.6	122	204	5.2	6.2	102	7070	5700	15	3450	2770	2.4	185	0.174	5.1
3/18	6.0	103	2.6	121	180	4.5	6.0	100	6970	5470	15	3430	2730	3.9	172	0.152	4.4
3/19	6.4	93	2.5	115	148	3.9	6.0	94	5800	4600	15	2690	2160	3.9	-1	0.167	4.0
3/20	6.2	88	2.3	104	136	3.5	6.1	98	6570	5440	16	3080	2480	3.9	205	0.182	5.0
3/21	6.2	98	2.5	112	149	3.9	6.1	98	6480	5280	15	2860	2350	3.4	200	0.152	4.1
3/22	6.1	87	2.2	120	140	3.6	5.4	89	6100	5070	15	2900	2350	4.8	219	0.165	4.2
3/23	6.1	86	2.2	141	194	4.9	5.2	85	6200	4970	16	2840	2330	4.0	222	0.156	4.0
3/24	6.0	85	2.1	132	185	4.6	4.3	72	6700	5670	16	2830	2270	3.0	193	0.140	3.9
3/25	6.8	112	3.2	144	171	4.8	3.7	54	7000	5770	16	2710	2210	4.0	199	0.131	3.8
3/26	6.8	159	4.5	109	129	3.7	3.7	54	6870	5570	16	2690	2170	4.3	228	0.130	3.7
3/27	6.7	78	2.2	92	129	3.6	3.9	58	6730	5660	16	2720	2250	4.6	227	0.149	4.2
3/28	7.5	100	3.1	106	155	4.8	4.2	56	5630	4760	15	2250	1640	4.8	276	0.089	2.1
TOTAL	130.1		58.3			91.2	112.9									2.339	63.9
AVER.	6.2	108	2.8	122	169	4.3	5.4	88	6740	5488	15	3248	2620	3.8	176	0.111	3.0

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGL DISPOSAL DISTRICT NO. 1 PERIOD: MARCH 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					******CLARIFIER*******				********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M							BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
3/ 8	90.7	1.25	0.49	-0.64	0.17	423	11.75	23.73	0.0	10.57	2.26	12.83	20.1	30	0.6	35	18	0.4	79	91
3/ 9	102.8	1.19	0.54	-0.46	0.35	457	12.64	25.74	0.2	10.54	2.78	13.32	13.3	28	0.6	34	22	0.5	81	89
3/10	110.8	1.12	0.59	0.22	0.90	490	14.08	27.44	1.5	10.95	4.78	15.73	9.6	43	1.1	44	27	0.7	66	87
3/11	104.0	1.19	0.50	-0.21	0.63	498	15.23	30.45	2.2	11.64	5.57	17.22	15.3	29	0.7	43	26	0.7	79	87
3/12	88.0	1.58	0.34	1.75	2.49	490	17.80	35.61	3.7	13.84	9.59	23.43	13.4	26	0.6	31	21	0.5	73	86
3/13	68.5	1.74	0.35	0.22	1.15	515	15.66	30.81	6.0	11.58	12.33	23.91	9.9	21	0.5	26	26	0.7	77	79
3/14	95.8	1.21	0.62	-1.15	-0.47	515	12.49	24.17	5.8	9.24	9.83	19.07	6.4	20	0.5	23	18	0.5	61	90
3/15	103.6	1.09	0.64	0.15	0.81	523	12.85	24.88	6.1	9.35	9.63	18.98	5.2	19	0.5	26	16	0.4	83	91
3/16	106.8	1.01	0.62	1.06	1.71	506	13.32	26.43	5.3	10.02	10.71	20.73	3.5	24	0.6	28	17	0.4	79	91
3/17	111.8	1.01	0.65	0.21	0.75	506	13.29	26.79	4.2	9.99	9.00	18.99	3.5	9	0.2	22	14	0.4	91	93
3/18	97.0	1.13	0.57	0.50	1.10	498	12.99	25.98	4.3	9.93	9.03	18.96	4.0	12	0.3	21	10	0.3	88	94
3/19	85.1	1.31	0.63	-0.13	0.56	531	10.87	21.06	5.0	7.79	8.44	16.23	3.4	26	0.7	28	15	0.4	72	90
3/20	75.7	1.30	0.49	1.41	2.11	515	12.06	23.92	4.6	8.92	8.96	17.88	3.4	11	0.3	23	9	0.2	88	93
3/21	83.0	1.29	0.57	0.40	1.12	515	11.19	22.21	4.7	8.28	8.99	17.27	3.8	17	0.4	24	13	0.3	83	91
3/22	76.7	1.40	0.52	0.48	1.15	506	11.17	21.05	4.5	8.40	8.18	16.58	3.7	11	0.3	26	11	0.3	87	92
3/23	106.3	1.02	0.73	0.36	0.83	506	10.94	20.26	4.2	8.22	7.89	16.11	3.8	13	0.3	26	13	0.3	88	93
3/24	99.7	1.05	0.70	0.34	0.84	498	10.72	18.40	3.4	8.20	7.30	15.49	3.7	12	0.3	23	14	0.4	86	92
3/25	104.4	1.08	0.76	0.43	1.14	565	11.63	17.96	4.0	7.85	8.59	16.43	4.0	11	0.3	33	14	0.4	90	92
3/26	78.8	1.36	0.58	0.68	1.44	565	11.55	17.83	4.6	7.79	9.37	17.16	4.2	12	0.3	25	12	0.3	92	91
3/27	77.6	1.26	0.55	0.72	1.39	556	11.50	18.20	4.7	7.88	9.33	17.21	3.8	11	0.3	22	12	0.3	86	91
3/28	104.4	1.05	0.91	-1.28	-0.55	623	10.65	16.62	3.0	6.52	5.62	12.13	4.5	20	0.6	28	18	0.6	80	88
TOTAL										197.51	168.15	365.66			10.2			8.9		
AVER.	93.5	1.22	0.59	0.21	0.93	514	12.59	23.79	3.9	9.41	8.01	17.41	6.8	19	0.5	28	16	0.4	82	96

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: MARCH 1977

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
3/29	8.0	83	2.8	155	175	5.8	3.9	49	6800	5770	15	2330	1910	4.8	211	0.0	0.0
3/30	8.9	102	3.8	134	174	6.5	4.8	54	7430	6260	16	2710	2220	4.2	297	0.055	1.7
3/31	8.0	102	3.4	140	169	5.6	4.8	60	7320	6040	16	2720	2180	4.6	257	0.130	4.0
TOTAL	24.9		10.0			17.9	13.5									0.185	5.7
AVER.	8.3	96	3.3	143	173	6.0	4.5	54	7183	6023	16	2587	2103	4.5	255	0.062	1.9

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 MEROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: MARCH 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	*********AERATION BASIN*********					*********CLARIFIER*********					*********INVENTORY*********				***SECONDARY EFFLUENT***					*% REM*	
DATE	# BOD /KCF	#O2/ #BODR	F/M BOD/ MLVSS	BIOSYNTHESIS NET	BIOSYNTHESIS GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	FLUX #/SF/DAY Q+R	DOB FT #7	DOB FT #9	BASIN SS TONS	CLAR SS TONS	TOTAL SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
3/29	125.8	0.91	1.06	-0.43	0.09	332	5.88	8.75	3.3	4.2	6.75	15.90	22.65	45.3	15	0.5	35	15	0.5	82	91
3/30	139.1	0.95	1.00	-0.81	-0.16	369	7.61	11.72	1.3	2.7	7.85	11.43	19.28	7.9	20	0.7	33	17	0.6	80	90
3/31	121.4	1.14	0.89	1.20	1.91	332	6.87	10.99	3.5	3.1	7.88	15.61	23.49	4.8	28	0.9	34	26	0.9	73	85
TOTAL											22.47	42.95	65.42			2.2			2.0		
AVER.	128.8	1.00	0.98	-0.01	0.62	345	6.79	10.49	2.7	3.3	7.49	14.32	21.81	19.3	21	0.7	34	19	0.7	78	89

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: APRIL 1977

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
	FLOW	SS	SS	TOC	BOD	BOD	FLOW		SS	VSS	TEMP	SS	VSS	DO	SVI	FLOW	SS
DATE	MGD	MG/L	TONS	MG/L	MG/L	TONS	MGD	%	MG/L	MG/L	C	MG/L	MG/L	MG/L		MGD	TONS
4/ 1	9.0	84	3.2	142	195	7.3	5.6	62	6530	5360	16	2650	2150	3.9	300	0.184	5.0
4/ 2	8.6	98	3.5	118	160	5.7	6.0	70	5600	4680	18	2270	1920	2.1	231	0.146	3.4
4/ 3	9.5	88	3.5	106	122	4.8	6.1	64	6770	5900	16	2560	2160	3.6	326	0.138	3.9
4/ 4	10.4	97	4.2	114	160	6.9	5.5	53	6370	4670	16	2300	1740	3.9	293	0.291	7.7
4/ 5	9.0	93	3.5	131	182	6.8	5.3	59	6170	5340	16	2590	2250	3.5	226	0.247	6.4
4/ 6	9.3	91	3.5	125	172	6.7	5.3	57	6000	5100	16	2530	2160	4.2	234	0.218	5.5
4/ 7	10.0	94	3.9	146	190	7.9	5.4	54	6100	5070	15	2270	1870	4.6	262	0.202	5.1
4/ 8	10.0	92	3.8	139	182	7.6	5.3	53	6130	5330	17	2280	1920	4.1	241	0.204	5.2
4/ 9	9.5	102	4.0	118	133	5.3	5.3	56	5760	4880	16	2330	1950	4.6	257	0.188	4.5
4/10	9.4	138	5.4	108	128	5.0	5.4	57	6040	5160	17	2310	1960	4.1	264	0.217	5.5
4/11	9.1	154	5.8	139	167	6.3	4.8	53	6200	5120	16	2310	1880	3.6	387	0.134	3.5
4/12	10.1	142	6.0	127	168	7.1	4.5	45	6480	5280	16	2190	1770	3.5	-1	0.234	6.3
4/13	10.1	115	4.8	111	157	6.6	3.2	32	7570	6500	17	2070	1760	3.4	298	0.161	5.7
4/14	10.0	106	4.4	130	159	6.6	3.2	32	8321	7200	16	2120	1840	3.8	265	0.147	5.1
4/15	10.1	132	5.6	140	148	6.2	3.3	33	8320	7000	16	2280	1940	4.8	321	0.140	4.9
4/16	10.0	111	4.6	100	147	6.1	3.3	33	8120	6720	17	2300	1920	4.0	275	0.190	6.4
4/17	10.1	93	3.9	93	111	4.7	3.2	32	8080	6760	16	2780	2410	4.6	296	0.206	6.9
4/18	10.2	115	4.9	110	153	6.5	3.3	32	7520	6160	16	2100	1700	4.8	309	0.185	5.8
4/19	11.1	177	8.2	138	203	9.4	3.1	28	7640	6440	16	2010	1650	4.4	232	0.159	5.2
4/20	10.8	160	7.2	136	191	8.6	3.2	30	9160	7840	16	2300	1970	4.2	242	0.114	4.4
4/21	10.3	100	4.3	126	169	7.3	3.3	32	9440	7880	17	2560	2110	3.2	238	0.140	5.5
4/22	10.0	106	4.4	127	169	7.0	3.2	32	9040	7600	17	2640	2180	3.4	242	0.117	4.4
4/23	10.0	125	5.2	104	141	5.9	3.3	33	8660	7200	18	2380	1950	4.3	225	0.139	5.0
4/24	9.9	74	3.1	90	110	4.5	3.2	32	8920	7440	18	2360	1900	4.4	250	0.139	5.2
4/25	10.3	79	3.4	100	133	5.7	3.3	32	8000	6760	18	2260	1870	3.8	267	0.152	5.1
4/26	10.1	87	3.7	126	164	6.9	3.2	32	8070	6900	18	2370	1950	4.3	230	0.106	3.6
4/27	10.2	92	3.9	115	176	7.5	3.2	31	8170	7070	17	2420	2030	6.5	262	0.201	6.8
4/28	9.8	112	4.6	146	171	7.0	3.3	34	9040	7640	17	2500	2090	6.1	221	0.137	5.2
4/29	10.1	113	4.8	124	169	7.1	3.3	33	9120	7400	17	2490	2020	5.2	245	0.150	5.7
4/30	9.5	78	3.1	94	129	5.1	3.2	34	8960	7400	17	2400	1980	6.2	-1	0.118	4.4
TOTAL	296.5		134.4			196.4	122.8									5.124	157.3
AVER.	9.9	108	4.5	121	159	6.5	4.1	42	7551	6325	17	2364	1967	4.2	266	0.171	5.2

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: APRIL 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					********CLARIFIER*********					********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
DATE	# BOD /KCF	#O2/ #BODR	F/M BOD/ MLVSS	BIOSYNTHESIS NET	BIOSYNTHESIS GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	FLUX #/SF/DAY Q+R	DOB FT #7	DOB FT #9	BASIN SS TONS	CLAR SS TONS	TOTAL SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
4/ 1	157.6	-1.00	1.18	-1.00	-1.00	374	7.53	12.21	2.2	4.4	7.67	13.93	21.60	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
4/ 2	123.6	-1.00	1.03	-1.00	-1.00	357	6.16	10.46	6.5	0.5	6.57	12.46	19.03	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
4/ 3	164.1	1.69	0.77	3.48	4.57	394	7.68	12.61	5.5	5.0	7.41	20.48	27.89	4.8	48	1.9	49	41	1.6	45	66
4/ 4	149.5	1.00	1.38	0.39	1.16	432	7.55	11.54	4.0	5.7	6.66	18.10	24.76	2.6	40	1.7	39	34	1.5	59	79
4/ 5	147.1	0.97	1.05	0.15	0.75	374	7.36	11.69	3.0	4.2	7.50	14.01	21.51	2.8	34	1.3	42	27	1.0	63	85
4/ 6	143.7	0.99	1.07	0.48	1.12	386	7.43	11.66	3.7	3.6	7.33	13.76	21.09	3.2	31	1.2	44	28	1.1	66	84
4/ 7	170.7	0.88	1.46	0.73	1.30	415	7.17	11.03	4.7	4.7	6.57	16.92	23.49	3.6	34	1.4	42	25	1.0	64	87
4/ 8	163.5	0.93	1.36	0.61	1.21	415	7.20	11.01	4.8	4.7	6.60	17.14	23.74	3.2	55	2.3	55	28	1.2	40	85
4/ 9	113.5	1.36	0.93	0.15	1.08	394	6.99	10.88	4.2	5.2	6.75	15.97	22.72	4.0	30	1.2	40	24	1.0	71	82
4/10	108.1	1.53	0.88	1.33	2.95	390	6.85	10.79	5.1	4.9	6.69	17.58	24.27	2.9	72	2.8	56	43	1.7	48	66
4/11	136.5	1.14	1.16	-0.05	1.14	378	6.64	10.14	5.1	4.7	6.69	17.76	24.45	4.5	51	1.9	54	38	1.4	67	77
4/12	152.4	0.91	1.38	0.30	1.26	419	6.98	10.09	5.0	4.8	6.34	18.56	24.91	3.4	25	1.1	34	21	0.9	82	88
4/13	142.4	0.98	1.30	0.62	1.46	419	6.60	8.69	4.8	4.3	5.99	20.47	26.47	3.9	26	1.1	30	21	0.9	77	87
4/14	142.8	1.00	1.24	0.95	1.71	415	6.69	8.83	5.3	4.7	6.14	24.21	30.35	5.0	24	1.0	36	19	0.8	77	88
4/15	134.3	1.05	1.11	-0.42	0.64	419	7.27	9.64	3.8	4.6	6.60	21.17	27.77	4.7	26	1.1	39	23	1.0	80	84
4/16	132.0	1.06	1.10	0.07	0.98	415	7.26	9.66	3.2	4.0	6.66	18.43	25.09	3.3	29	1.2	35	26	1.1	74	82
4/17	100.7	1.28	0.67	2.60	3.65	419	8.86	11.67	4.8	4.7	8.05	22.59	30.64	3.8	28	1.2	29	22	0.9	70	80
4/18	140.2	1.06	1.32	-1.60	-0.64	423	6.76	8.95	1.2	3.7	6.08	13.12	19.20	2.3	57	2.4	38	34	1.4	50	78
4/19	202.4	0.67	1.97	0.26	1.29	461	7.04	9.01	2.6	3.7	5.82	16.18	22.01	2.9	49	2.3	38	31	1.4	72	85
4/20	185.3	-1.00	1.51	-1.00	-1.00	448	7.84	10.16	2.6	2.6	6.66	16.61	23.27	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
4/21	156.4	1.07	1.19	0.82	1.56	428	8.32	10.99	2.5	3.0	7.41	17.76	25.17	3.5	38	1.6	42	34	1.5	62	80
4/22	151.8	1.10	1.12	0.81	1.62	415	8.33	11.00	3.2	3.9	7.65	20.32	27.96	4.6	39	1.6	44	38	1.6	63	78
4/23	126.6	1.12	1.04	0.41	1.50	415	7.51	9.99	3.7	4.5	6.89	21.69	28.58	4.3	37	1.5	38	26	1.1	70	82
4/24	97.8	1.54	0.83	1.86	2.81	411	7.37	9.76	4.5	4.3	6.83	23.51	30.35	4.2	51	2.1	42	32	1.3	31	71
4/25	123.0	1.21	1.05	-0.12	0.62	428	7.35	9.70	4.1	4.0	6.55	19.81	26.35	3.9	41	1.8	36	27	1.2	48	80
4/26	148.8	1.21	1.22	0.44	1.12	419	7.56	9.95	4.2	4.1	6.86	20.35	27.21	5.2	39	1.6	40	35	1.5	55	79
4/27	161.2	1.02	1.27	0.42	1.09	423	7.79	10.24	3.6	3.2	7.01	17.80	24.81	2.8	44	1.9	39	40	1.7	52	77
4/28	150.5	1.26	1.15	1.60	2.56	407	7.73	10.34	3.7	3.7	7.24	20.94	28.18	3.2	91	3.7	63	54	2.2	19	68
4/29	153.3	1.07	1.22	0.64	1.49	419	7.94	10.53	3.0	4.2	7.21	20.70	27.92	3.2	69	2.9	46	36	1.5	39	79
4/30	110.1	1.73	0.89	1.96	2.91	394	7.20	9.62	5.4	3.2	6.95	23.21	30.16	4.2	71	2.8	52	47	1.9	9	64
TOTAL											205.42	555.55	760.96			40.7			35.3		
AVER.	141.0	1.14	1.16	0.70	1.59	410	7.37	10.43	4.0	4.1	6.85	18.52	25.37	3.7	44	1.8	42	32	1.3	58	79

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: MAY 1977

MAROX FLOWS AND CONCENTRATIONS

	*********SECONDARY INFLUENT*********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
5/ 1	10.1	73	3.1	87	118	5.0	3.3	33	8400	6930	18	2310	1890	6.2	279	0.149	5.2
5/ 2	10.0	98	4.1	101	139	5.8	3.8	38	7500	6200	18	2340	1920	6.1	273	0.207	6.5
5/ 3	10.0	93	3.9	114	162	6.8	4.3	43	7370	6270	18	2480	2060	5.6	221	0.162	5.0
5/ 4	10.3	92	4.0	122	184	7.9	4.8	47	7130	5960	18	2420	2040	5.6	-1	0.100	3.0
5/ 5	11.6	188	9.1	160	180	8.7	5.5	47	6530	5530	17	2550	2140	6.6	198	0.171	4.7
5/ 6	11.6	101	4.9	139	170	8.2	6.0	52	7080	5840	19	2680	2240	7.3	187	0.206	6.1
5/ 7	11.6	74	3.6	93	138	6.7	6.0	52	7230	6000	17	2750	2260	6.3	-1	0.213	6.4
5/ 8	12.3	67	3.4	84	112	5.7	5.9	48	6560	5480	19	2420	2020	5.8	-1	0.201	5.5
5/ 9	12.1	90	4.5	106	150	7.6	5.9	49	5880	5040	19	2150	1770	5.9	195	0.210	5.1
5/10	12.6	118	6.2	130	170	8.9	5.7	45	7320	6040	19	2430	2000	5.5	194	0.222	6.8
5/11	12.9	257	13.8	182	205	11.0	6.0	47	7270	6140	19	2590	2180	5.4	200	0.224	6.8
5/12	13.2	138	7.6	132	171	9.4	5.9	45	7470	6370	19	2670	2260	1.5	205	0.267	8.3
5/13	11.3	101	4.8	106	138	6.5	5.9	52	7830	6830	19	2990	2530	5.5	142	0.265	8.7
5/14	11.8	88	4.3	91	121	6.0	5.9	50	6730	5760	18	2690	2300	6.1	169	0.249	7.0
5/15	12.9	84	4.5	94	109	5.9	6.0	47	7120	5840	18	2640	2190	6.5	174	0.201	6.0
5/16	11.7	84	4.1	104	134	6.5	6.0	51	6560	5360	19	2740	2210	6.1	163	0.178	4.9
5/17	12.3	125	6.4	112	162	8.3	6.0	49	7280	5920	19	2770	2280	5.9	140	0.168	5.1
5/18	12.3	95	4.9	126	157	8.1	6.0	49	7060	5900	19	2770	2240	6.7	162	0.126	3.7
5/19	12.4	95	4.9	134	158	8.2	6.0	48	7670	6470	19	2970	2450	6.3	156	0.162	5.2
5/20	12.2	193	9.8	146	182	9.3	6.1	50	7630	6400	19	3050	2500	6.4	141	0.186	5.9
5/21	12.2	84	4.3	103	139	7.1	6.1	50	-1	-1	18	3000	2430	6.7	144	0.225	-1.0
5/22	11.9	99	4.9	78	104	5.2	6.0	50	6730	5760	19	2740	2250	6.2	144	0.214	6.0
5/23	12.5	-1	-1.0	-1	-1	-1.0	6.2	50	7700	6330	18	2940	2400	6.2	119	0.182	5.8
5/24	12.1	106	5.3	132	169	8.5	5.9	49	7840	6520	19	2860	2370	6.1	117	0.149	4.9
5/25	11.7	103	5.0	114	161	7.9	5.9	50	8040	6640	19	3090	2520	6.8	117	0.156	5.2
5/26	11.9	100	5.0	121	174	8.6	6.0	50	8170	6570	19	2900	2380	6.4	126	0.173	5.9
5/27	12.6	84	4.4	112	169	8.9	6.2	49	8840	7320	19	3140	2600	5.8	128	0.177	6.5
5/28	11.3	99	4.7	109	154	7.3	6.1	54	10000	8300	19	3380	2800	6.4	134	0.196	8.2
5/29	11.5	69	3.3	78	108	5.2	5.2	45	9330	7660	19	3180	2600	6.6	106	0.161	6.3
5/30	10.7	79	3.5	112	102	4.6	5.3	50	8960	7200	20	3310	2620	6.4	105	0.180	6.7
5/31	12.3	83	4.3	98	131	6.7	5.0	41	8720	7320	20	2910	2400	5.4	114	0.169	6.1
TOTAL	365.9		156.6			220.2	174.9									5.849	177.4
AVER.	11.8	105	5.2	114	145	7.3	5.6	48	7599	6330	19	2770	2285	6.0	163	0.189	5.9

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

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      10/18/77                   METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1          PERIOD: MAY 1977

                                        MAROX LOADING, INVENTORY AND PERFORMANCE

         ********AERATION BASIN******** ********CLARIFIER*********   ********INVENTORY********    ***SECONDARY EFFLUENT*** *% REM*
                            F/M                                      BASIN  CLAR  TOTAL
         # BOD  #O2/  BOD/ BIOSYNTHESIS OVERFLOW   FLUX     DOB DOB    SS     SS     SS    SRT      SS   SS  TOC  BOD  BOD    SS BOD
  DATE  /KCF #BODR MLVSS   NET  GROSS  G/SF/DY  #/SF/DAY    FT  FT   TONS   TONS   TONS   DAYS    MG/L TONS MG/L MG/L TONS
                                                 Q    Q+R   #7  #9

  5/ 1 107.1  1.38  0.91  1.03  1.86     419    7.36  9.77 4.8 4.7   6.69  23.49  30.18  4.4      39  1.6  36   30  1.3    47 75
  5/ 2 124.9  1.38  1.04 -0.25  0.71     415    7.39 10.19 3.3 4.8   6.78  18.57  25.35  3.2      33  1.4  33   37  1.5    66 73
  5/ 3 145.5  1.08  1.13  0.20  0.87     415    7.83 11.19 2.9 4.7   7.18  17.41  24.59  4.3      19  0.8  30   24  1.0    80 85
  5/ 4 170.2  1.06  1.34  0.12  0.74     428    7.87 11.53 4.2 3.8   7.01  17.49  24.50  5.1      42  1.8  44   37  1.6    54 80
  5/ 5 187.5  1.06  1.40  0.26  1.62     482    9.34 13.76 5.4 5.4   7.38  20.20  27.58  3.6      64  3.1  54   42  2.0    66 77
  5/ 6 177.1  1.05  1.27  0.78  1.47     482    9.81 14.89 5.4 6.0   7.76  22.87  30.63  4.2      26  1.3  32   24  1.2    74 86
  5/ 7 143.8  1.18  1.02  0.68  1.31     482   10.07 15.28 5.3 5.5   7.96  22.37  30.33  3.9      26  1.3  33   22  1.1    65 84
  5/ 8 123.7  1.61  0.98 -0.20  0.67     511    9.40 13.90 4.2 4.7   7.01  17.44  24.45  2.9      59  3.0  44   35  1.8    12 69
  5/ 9 163.0  1.03  1.48  0.13  0.81     502    8.21 12.22 5.1 5.3   6.23  17.65  23.88  4.0      16  0.8  28   18  0.9    82 88
  5/10 192.4  0.92  1.54  0.64  1.41     523    9.66 14.04 4.8 4.7   7.04  20.47  27.51  3.6      17  0.9  34   18  0.9    86 89
  5/11 237.5  1.09  1.75  0.90  2.94     535   10.55 15.45 6.3 6.1   7.50  25.15  32.65  2.2     148  8.0  82   79  4.2    42 61
  5/12 202.7  0.92  1.44  0.42  1.30     548   11.12 16.10 6.2 6.3   7.73  26.01  33.74  3.4      28  1.5  34   27  1.5    80 84
  5/13 140.1  1.39  0.89  0.43  1.25     469   10.66 16.23 5.3 4.9   8.66  23.15  31.81  3.5      11  0.5  27   15  0.7    89 89
  5/14 128.2  1.32  0.89 -0.91 -0.10     490   10.02 15.03 3.6 4.0   7.79  15.89  23.68  3.1      12  0.6  24   12  0.6    86 90
  5/15 126.3  1.50  0.92  0.32  1.21     535   10.75 15.75 3.4 3.2   7.65  15.19  22.83  3.3      19  1.0  23   15  0.8    77 86
  5/16 140.8  1.29  1.02 -0.40  0.31     486   10.12 15.31 2.3 2.2   7.94  10.84  18.78  3.2      20  1.0  23   17  0.8    76 67
  5/17 179.0  1.07  1.26  0.24  1.11     511   10.75 16.00 2.0 2.9   8.02  12.70  20.72  3.3      22  1.1  28   19  1.0    82 88
  5/18 173.5 -1.00  1.24 -1.00 -1.00     511   10.75 16.00 2.9 4.5   8.02  16.40  24.42 -1.0      -1 -1.0  -1   -1 -1.0    -1 -1
  5/19 176.0  1.18  1.15  0.72  1.40     515   11.62 17.25 3.2 5.2   8.60  19.52  28.12  4.4      22  1.1  28   20  1.0    77 87
  5/20 199.4  1.02  1.28 -0.06  1.16     506   11.75 17.62 4.0 5.2   8.83  20.81  29.64  3.8      37  1.9  34   24  1.2    81 87
  5/21 152.3  1.23  1.00 -1.00 -1.00     506   11.55 17.33 4.3 3.8   8.69  -1.00  -1.00 -1.0      14  0.7  27   21  1.1    83 85
  5/22 111.2  1.55  0.79 -1.00 -1.00     494   10.29 15.48 3.7 4.2   7.94  16.36  24.29  3.4      22  1.1  28   16  0.8    78 85
  5/23  -1.0 -1.00 -1.00 -1.00 -1.00     519   11.60 17.35 2.7 3.0   8.51  14.84  23.35  3.4      21  1.1  22   15  0.8    -1 -1
  5/24 183.7  1.08  1.24  0.07  0.76     502   10.92 16.25 2.5 3.2   8.28  15.11  23.39  4.0      19  1.0  28   15  0.8    82 91
  5/25 169.2  1.26  1.08  0.51  1.24     486   11.41 17.17 2.0 4.2   8.95  16.41  25.36  3.9      27  1.3  32   20  1.0    74 88
  5/26 186.0  1.15  1.25 -0.39  0.26     494   10.89 16.39 1.3 2.4   8.40  12.01  20.41  2.9      21  1.0  28   20  1.0    79 89
  5/27 191.3  1.10  1.18  1.57  2.12     523   12.49 18.63 3.5 4.2   9.09  21.08  30.17  4.1      16  0.8  32   15  0.8    81 91
  5/28 156.3  2.01  0.69  2.09  3.16     469   12.06 18.56 3.2 3.7   9.79  22.02  31.80  2.6      83  3.9  55   62  2.9    16 60
  5/29 111.6  1.94  0.69  0.42  1.27     477   11.54 16.76 3.1 3.2   9.21  19.26  28.47  3.4      42  2.0  32   27  1.3    39 75
  5/30  98.0  1.88  0.60  1.00  1.86     444   11.18 16.72 3.2 3.5   9.59  19.32  28.90  4.0      11  0.5  20   10  0.4    86 90
  5/31 144.7  0.90  0.97 -0.67  0.11     511   11.30 15.89 2.1 2.0   8.43  13.61  22.04  2.9      26  1.3  27   25  1.3    69 81

 TOTAL                                                            248.66 553.62 793.58                 47.5           37.3

 AVER. 158.1  1.26  1.12  0.36  1.22     490   10.33 15.29 3.7 4.2   8.02  18.45  26.45  3.6      32  1.6  33   25  1.2    69 83



 -1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS
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10/18/77 METROPOLIAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JUNE 1977

MAROX FLOWS AND CONCENTRATIONS

	*********SECONDARY INFLUENT*********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
6/ 1	11.8	97	4.8	112	169	8.3	5.3	45	8880	7600	20	3140	2680	4.3	112	0.135	5.0
6/ 2	12.2	107	5.4	115	176	9.0	5.4	44	9470	8000	20	3190	2680	6.6	118	0.131	5.2
6/ 3	12.0	89	4.5	112	169	8.5	5.2	43	9430	8100	21	3160	2700	5.5	117	0.109	4.3
6/ 4	11.9	95	4.8	98	136	6.7	5.7	48	8880	7600	20	3190	2700	6.0	136	0.152	5.6
6/ 5	12.1	86	4.3	87	112	5.7	4.8	40	9320	7880	19	2840	2400	6.4	114	0.206	8.0
6/ 6	12.4	82	4.2	98	124	6.4	5.2	42	8840	7440	19	2830	2280	3.6	119	0.154	5.7
6/ 7	13.0	88	4.8	111	173	9.4	5.4	42	9040	7760	19	2870	2410	3.4	114	0.163	6.1
6/ 8	12.7	101	5.3	126	170	9.0	5.5	43	9770	8270	20	3310	2750	5.2	114	0.174	7.1
6/ 9	13.4	75	4.2	108	162	9.1	5.7	43	9530	8000	20	3040	2590	3.5	108	0.147	5.8
6/10	13.7	80	4.6	118	155	8.9	5.9	43	9600	8430	20	3270	2710	3.6	122	0.204	8.2
6/11	13.1	80	4.4	100	130	7.1	5.7	44	9930	8400	20	3260	2730	4.1	110	0.180	7.5
6/12	14.1	89	5.2	72	109	6.4	5.9	42	9600	7880	19	3140	2520	5.3	94	0.161	6.4
6/13	12.9	-1	-1.0	-1	-1	-1.0	5.4	42	9440	7840	20	2900	2360	6.5	96	0.165	6.5
6/14	13.6	102	5.5	110	166	9.0	5.7	44	9400	7800	20	2890	2380	-1.0	92	0.146	5.7
6/15	12.1	91	4.6	110	144	7.3	5.7	47	9440	8000	20	3540	2970	-1.0	114	0.101	4.0
6/16	14.7	114	7.0	114	131	8.0	5.8	39	10300	8800	20	3220	2690	-1.0	95	0.175	7.5
6/17	14.3	-1	-1.0	-1	-1	-1.0	6.0	42	11100	9400	20	3310	2800	1.6	95	0.198	9.2
6/18	14.1	65	3.8	88	114	6.7	6.0	43	10600	8900	20	3370	2710	4.5	102	0.180	8.0
6/19	13.9	71	4.1	74	90	5.2	6.0	43	10600	8900	20	3190	2670	3.7	114	0.158	7.0
6/20	13.8	-1	-1.0	-1	-1	-1.0	5.9	43	10200	8800	20	3210	2660	3.9	106	0.147	6.3
6/21	13.7	92	5.3	128	146	8.3	5.8	42	10600	9100	20	3260	2790	5.0	99	0.153	6.8
6/22	14.4	69	4.1	108	149	8.9	5.9	41	11200	9800	20	3300	2760	2.4	105	0.162	7.6
6/23	14.9	90	5.6	108	136	8.5	6.2	42	10900	9200	20	3300	2800	2.6	108	0.159	7.2
6/24	13.3	78	4.3	102	136	7.5	5.9	44	10500	9100	21	3100	2640	2.2	126	0.141	6.2
6/25	14.1	139	8.2	107	120	7.1	6.1	43	10600	9500	21	3470	2990	3.5	126	0.156	6.9
6/26	13.6	262	14.9	130	165	9.4	5.9	43	10400	8900	21	3380	2850	2.8	148	0.198	6.6
6/27	13.7	146	8.3	117	138	7.9	5.7	42	10700	8900	21	3120	2550	3.7	120	0.219	9.8
6/28	13.3	109	6.0	94	124	6.9	5.8	44	10400	8800	20	3530	2850	4.1	102	0.206	8.9
6/29	14.3	234	14.0	127	187	11.2	5.7	40	10800	9200	20	3980	3200	4.2	129	0.171	7.7
6/30	13.7	172	9.8	123	152	8.7	6.1	45	11800	9600	20	3810	3100	3.9	130	0.183	9.0
TOTAL	400.2		162.1			214.8	171.3									4.934	207.6
AVER.	13.3	100	6.0	100	144	8.0	5.7	43	10042	8530	20	3237	2697	4.2	113	0.164	6.9

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JUNE 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					********CLARIFIER*********					********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
DATE	# BOD /KCF	#O2/ #BODR	F/M BOD/ MLVSS	BIOSYNTHESIS NET	BIOSYNTHESIS GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	FLUX #/SF/DAY Q+R	DOB FT #7	DOB FT #9	BASIN SS TONS	CLAR SS TONS	TOTAL SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
6/ 1	179.1	-1.00	1.07	-1.00	-1.00	490	11.70	16.95	2.1	2.0	9.09	13.86	22.96	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
6/ 2	192.9	1.12	1.15	0.03	0.72	506	12.28	17.72	1.5	1.9	9.24	13.27	22.51	3.7	19	1.0	24	21	1.1	82	88
6/ 3	182.2	-1.00	1.08	-1.00	-1.00	498	11.97	17.16	1.8	2.6	9.15	15.37	24.52	-1.0	-1	-1.0	-1	-1	-1.0	-1	-1
6/ 4	145.4	1.46	0.86	-0.30	0.48	494	11.98	17.72	1.1	2.0	9.24	11.83	21.07	3.3	15	0.7	24	12	0.6	84	91
6/ 5	121.7	1.64	0.81	2.41	3.27	502	10.85	15.15	2.6	4.4	8.22	20.73	28.96	3.4	12	0.6	20	12	0.6	86	89
6/ 6	138.1	1.57	0.97	0.22	0.96	515	11.08	15.72	2.5	4.6	8.20	19.87	28.06	4.4	14	0.7	25	13	0.7	83	90
6/ 7	202.0	1.09	1.34	0.32	0.87	540	11.78	16.67	2.7	4.5	8.31	20.52	28.83	4.2	12	0.7	22	13	0.7	86	92
6/ 8	193.9	1.16	1.13	0.45	1.09	527	13.27	19.02	2.4	4.0	9.59	20.39	29.98	3.8	15	0.8	24	14	0.7	85	92
6/ 9	195.0	1.18	1.21	-0.23	0.27	556	12.86	18.33	1.3	3.6	8.80	17.06	25.86	4.0	10	0.6	30	13	0.7	87	92
6/10	190.7	1.23	1.13	1.55	2.13	569	14.14	20.23	4.0	4.3	9.47	24.21	33.68	3.7	16	0.9	26	16	0.9	80	90
6/11	153.0	1.66	0.90	0.04	0.72	544	13.48	19.35	3.0	3.4	9.44	20.73	30.17	3.7	12	0.7	26	13	0.7	85	90
6/12	138.0	1.90	0.88	0.89	1.86	585	13.97	19.82	3.8	4.2	9.09	23.55	32.64	4.3	19	1.1	21	17	1.0	79	84
6/13	-1.0	-1.00	-1.00	-1.00	-1.00	535	11.81	16.75	3.0	3.6	8.40	20.14	28.53	4.0	12	0.6	20	11	0.6	-1	-1
6/14	193.8	1.16	1.31	-0.18	0.50	540	11.86	17.06	2.6	2.8	8.37	17.47	25.84	3.8	19	1.0	31	17	0.9	81	90
6/15	156.5	1.49	0.84	0.70	1.43	502	13.52	19.89	3.1	3.1	10.25	19.27	29.52	5.5	28	1.4	31	18	0.9	69	68
6/16	173.0	1.39	1.03	0.49	1.47	610	14.94	20.84	3.4	3.3	9.33	22.21	31.53	3.7	15	0.9	15	15	0.9	87	89
6/17	-1.0	-1.00	-1.00	-1.00	-1.00	594	14.94	21.21	2.9	2.0	9.59	19.36	28.95	2.9	14	0.8	28	14	0.8	-1	-1
6/18	144.4	1.59	0.85	1.11	1.75	595	15.00	21.38	3.0	2.9	9.76	20.91	30.67	3.5	12	0.7	24	13	0.8	82	89
6/19	112.4	2.05	0.67	0.52	1.42	577	14.00	20.04	3.1	2.5	9.24	20.19	29.42	3.8	13	0.8	22	11	0.6	82	83
6/20	-1.0	-1.00	-1.00	-1.00	-1.00	573	13.98	19.96	3.2	2.4	9.30	19.42	28.72	4.1	13	0.7	24	10	0.6	-1	-1
6/21	179.7	1.31	1.03	0.61	1.30	569	14.10	20.07	4.2	1.8	9.44	21.16	30.60	3.8	21	1.2	26	14	0.8	77	90
6/22	192.7	1.18	1.12	0.88	1.39	598	15.00	21.15	3.2	3.4	9.56	23.89	33.45	4.0	15	0.9	28	13	0.8	78	91
6/23	182.0	1.31	1.04	0.23	0.97	619	15.52	21.98	2.7	3.8	9.56	23.00	32.56	4.0	16	1.0	28	14	0.9	82	90
6/24	162.5	1.35	0.99	0.30	0.94	552	13.01	18.79	3.2	3.5	8.98	22.64	31.61	4.3	20	1.1	28	15	0.8	74	89
6/25	152.0	1.19	0.81	0.08	1.35	585	15.44	22.12	3.4	3.2	10.05	22.61	32.66	4.3	13	0.8	24	10	0.6	91	92
6/26	201.6	0.85	1.13	0.76	2.48	565	14.51	20.80	6.6	5.2	9.79	34.55	44.34	4.6	20	1.1	26	13	0.7	92	92
6/27	169.8	1.20	1.07	-0.56	0.59	569	13.49	19.11	4.7	4.5	9.04	29.18	38.22	3.7	11	0.6	28	10	0.6	92	93
6/28	148.1	1.46	0.83	-0.66	0.31	552	14.02	21.28	3.0	2.8	10.22	20.28	30.50	3.2	13	0.7	25	11	0.6	88	91
6/29	240.2	0.85	1.20	0.07	1.40	594	17.96	25.13	3.9	3.6	11.53	25.26	36.79	4.4	12	0.7	24	11	0.7	95	94
6/30	187.0	1.28	0.97	-0.06	1.15	569	16.48	23.81	3.4	3.3	11.03	25.44	36.47	3.8	11	0.6	22	10	0.6	94	93
TOTAL											281.26	628.37	909.63			23.6			20.9		
AVER.	171.4	1.35	1.02	0.39	1.23	554	13.66	19.51	3.0	3.3	9.38	20.95	30.32	3.9	15	0.8	25	13	0.7	84	90

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JULY 1977

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
7/ 1	14.0	105	6.1	104	141	8.2	5.8	41	12800	10700	20	4550	3790	1.6	127	0.190	10.1
7/ 2	13.3	91	5.0	90	-1	-1.0	5.6	42	12600	10800	21	3740	3090	2.1	113	0.152	8.0
7/ 3	12.9	94	5.1	78	115	6.2	5.4	42	11900	9900	22	3700	3070	3.7	124	0.115	5.7
7/ 4	13.3	107	5.9	-1	151	8.4	5.6	42	12300	10300	20	3570	2940	2.9	121	0.122	6.3
7/ 5	14.7	105	6.4	100	130	8.0	6.3	43	12000	10000	20	3800	3130	1.1	113	0.128	6.4
7/ 6	14.3	93	5.5	98	132	7.9	5.9	41	12900	10800	22	3720	3060	1.7	133	0.148	8.0
7/ 7	14.2	98	5.8	92	113	6.7	5.7	40	13200	10900	21	3920	3270	2.8	126	0.164	9.0
7/ 8	14.5	96	5.8	90	125	7.6	6.0	41	12600	10500	21	-1	-1	2.8	134	0.119	6.3
7/ 9	13.3	86	4.8	82	125	6.9	5.9	44	12200	10200	21	3750	3080	3.8	133	0.127	6.5
7/10	14.2	83	4.9	73	112	6.6	5.6	39	12300	10300	21	3650	2960	3.2	112	0.128	6.6
7/11	14.2	99	5.9	98	119	7.0	5.6	39	12600	10400	23	3910	3220	4.2	130	0.147	7.7
7/12	14.6	112	6.8	103	137	8.3	5.7	39	12300	10300	23	3510	2880	4.2	97	0.130	6.7
7/13	14.5	104	6.3	88	108	6.5	5.6	39	12300	10300	23	3720	3060	3.9	96	0.121	6.2
7/14	15.3	94	6.0	88	114	7.3	6.0	39	12700	10700	22	4690	3940	4.3	97	0.109	5.8
7/15	13.9	97	5.6	82	108	6.3	5.6	40	12400	10600	22	3680	3010	2.1	104	0.134	6.9
7/16	14.3	150	8.9	98	132	7.9	5.9	41	14300	11500	22	3750	3020	4.2	99	0.158	9.4
7/17	15.3	90	5.7	72	90	5.7	6.0	39	10500	8500	23	3550	2890	4.5	86	0.135	5.9
7/18	14.8	85	5.2	86	104	6.4	5.4	36	12800	10600	22	3440	2790	2.8	92	0.115	6.1
7/19	14.9	100	6.2	87	116	7.2	5.9	40	12600	10500	22	3780	3140	1.1	94	0.103	5.4
7/20	15.1	106	6.7	102	133	8.4	5.9	39	13000	10600	21	3790	3060	0.7	95	0.103	5.6
7/21	15.6	112	7.3	74	88	5.7	5.9	38	13900	10900	22	3730	2900	2.4	83	0.099	5.7
7/22	14.4	114	6.8	82	96	5.8	5.8	40	14200	11400	22	4010	3180	2.5	92	0.109	6.5
7/23	14.5	113	6.8	86	92	5.6	6.0	41	13900	11300	22	3870	3010	3.9	108	0.153	8.9
7/24	14.5	104	6.3	68	92	5.6	6.0	41	13800	11400	22	3860	3060	3.4	88	0.129	7.4
7/25	15.2	97	6.1	74	94	6.0	6.0	39	13600	10800	22	3820	2970	3.1	87	0.118	6.8
7/26	14.9	94	5.8	74	93	5.8	5.8	39	14500	11300	22	3990	3100	2.0	97	0.103	6.2
7/27	14.4	79	4.7	63	80	4.8	5.7	40	14900	11400	22	4080	3080	2.0	96	0.088	5.5
7/28	12.1	84	4.2	59	68	3.4	5.9	49	13600	10400	22	4240	3160	1.9	107	0.208	11.8
7/29	12.9	109	5.9	72	82	4.4	5.8	45	16100	12100	22	4210	3130	2.1	90	0.098	6.6
7/30	13.5	111	6.2	72	99	5.6	5.7	42	14000	10800	22	3860	2930	2.1	94	0.107	6.2
7/31	13.5	97	5.5	76	89	5.0	5.8	43	15900	12700	-1	4210	3230	2.5	90	0.080	5.3
TOTAL	441.1		184.6			195.1	179.8									3.940	215.4
AVER.	14.2	100	6.0	84	109	6.5	5.8	41	13190	10739	22	3870	3106	2.8	105	0.127	6.9

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: JULY 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					********CLARIFIER*********					********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M								BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT #7	DOB FT #9	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
7/ 1	177.3	1.41	0.75	0.67	1.50	581	20.11	28.44	2.7	2.5	13.18	23.20	36.38	3.3	17	1.0	23	15	0.9	84	89
7/ 2	-1.0	-1.00	-1.00	-1.00	-1.00	552	15.70	22.31	2.8	1.8	10.83	21.11	31.94	3.6	15	0.8	22	12	0.7	84	-1
7/ 3	133.3	1.78	0.70	0.15	1.05	535	15.07	21.37	2.9	2.0	10.72	20.76	31.47	5.0	12	0.6	22	11	0.6	87	90
7/ 4	180.4	1.29	0.98	0.23	0.98	552	14.99	21.30	3.0	2.1	10.34	22.02	32.36	4.7	10	0.6	-1	10	0.6	91	93
7/ 5	171.7	1.44	0.88	0.14	1.04	610	17.63	25.19	2.6	2.5	11.01	21.48	32.49	4.4	15	0.9	24	13	0.8	86	90
7/ 6	169.5	1.45	0.89	-0.17	0.61	594	16.79	23.72	2.4	0.7	10.77	17.19	27.96	3.2	15	0.9	24	13	0.8	84	90
7/ 7	144.1	1.70	0.71	1.26	2.23	589	17.57	24.62	2.3	1.6	11.35	20.01	31.36	3.2	15	0.9	27	12	0.7	85	69
7/ 8	162.8	1.51	-1.00	-1.00	-1.00	602	-1.00	-0.01	2.4	2.1	-1.00	20.83	-1.00	-1.0	14	0.8	20	12	0.7	85	90
7/ 9	149.3	1.53	0.78	-1.00	-1.00	552	15.74	22.73	3.1	2.6	10.86	23.51	34.37	4.7	14	0.8	24	12	0.7	64	90
7/10	142.9	1.73	0.77	-0.25	0.60	589	16.36	22.61	2.6	1.7	10.57	19.77	30.34	4.0	16	0.9	27	14	0.8	81	88
7/11	151.8	1.58	0.76	0.71	1.62	589	17.53	24.44	2.8	1.8	11.32	21.11	32.44	3.9	11	0.7	22	10	0.6	89	92
7/12	179.7	1.31	1.00	-0.01	0.88	606	16.18	22.49	3.0	1.8	10.17	21.17	31.34	4.0	19	1.2	25	12	0.7	83	91
7/13	140.7	1.75	0.74	0.35	1.44	602	17.03	23.60	2.5	2.5	10.77	21.74	32.51	4.5	16	1.0	26	12	0.7	85	89
7/14	156.7	1.58	0.64	0.59	1.49	635	22.65	31.53	2.7	2.2	13.58	22.15	35.73	5.4	14	0.9	22	10	0.6	85	91
7/15	134.8	1.89	0.72	-0.25	0.77	577	16.15	22.65	2.7	2.1	10.66	21.35	32.00	4.0	18	1.0	22	13	0.8	81	88
7/16	169.5	1.47	0.90	0.34	1.59	594	16.93	23.91	2.1	1.7	10.86	21.35	32.21	2.9	29	1.7	27	12	0.7	81	91
7/17	123.7	2.03	0.69	-1.02	0.14	635	17.14	23.87	2.1	1.5	10.28	15.19	25.47	3.4	24	1.5	22	13	0.8	73	86
7/18	138.3	1.76	0.79	1.13	2.07	614	16.07	21.93	2.3	1.8	9.96	19.99	29.95	4.2	16	1.0	23	13	0.8	81	88
7/19	155.2	1.61	0.79	0.03	1.01	619	17.78	24.82	2.1	1.8	10.95	19.10	30.04	4.8	14	0.9	24	14	0.9	86	88
7/20	180.4	1.40	0.95	0.71	1.59	627	18.06	25.12	2.8	2.8	10.98	24.76	35.73	5.6	12	0.8	22	13	0.8	89	90
7/21	123.3	2.13	0.68	-0.50	0.94	640	18.37	25.31	2.2	2.4	10.80	23.29	34.09	5.3	10	0.7	20	10	0.7	91	89
7/22	124.2	1.99	0.63	1.05	2.34	598	18.23	25.57	2.9	2.9	11.61	27.69	39.30	5.5	12	0.7	[illegible]	8	0.5	89	92
7/23	119.8	2.12	0.64	-0.28	1.08	602	17.71	25.04	2.4	2.4	11.21	23.93	35.14	3.7	12	0.7	18	9	0.5	89	90
7/24	119.8	2.14	0.63	-0.15	1.12	602	17.67	24.98	2.0	2.0	11.18	21.23	32.41	3.9	14	0.8	16	10	0.6	87	89
7/25	128.3	2.62	0.69	0.02	1.54	631	18.33	25.56	1.8	1.8	11.06	19.97	31.03	4.1	13	0.8	20	30	1.9	87	68
7/26	124.5	1.96	0.64	1.24	2.40	619	18.77	26.07	2.7	1.7	11.56	23.63	35.19	4.5	27	1.7	27	12	0.7	71	87
7/27	103.5	2.42	0.54	0.81	1.97	598	18.54	25.89	2.8	1.7	11.82	24.63	36.44	5.4	22	1.3	22	12	0.7	72	85
7/28	73.9	3.56	0.37	-0.50	0.95	502	16.19	24.09	1.1	0.8	12.28	14.39	26.67	2.1	15	0.8	20	10	0.5	82	85
7/29	95.0	2.53	0.49	1.13	2.60	535	17.14	24.85	1.0	1.0	12.19	17.41	29.60	4.0	16	0.9	22	8	0.4	85	90
7/30	120.0	2.03	0.66	-0.89	0.37	560	16.45	23.39	1.0	0.4	11.18	13.22	24.39	3.5	14	0.8	20	11	0.6	87	89
7/31	107.9	2.30	0.54	1.18	2.41	560	17.94	25.65	1.3	0.6	12.19	16.83	29.02	4.8	14	0.8	20	10	0.6	86	89
TOTAL											336.23	643.98	959.39			28.8			22.4		
AVER.	140.1	1.87	0.72	0.27	1.37	591	17.36	23.65	2.4	1.8	11.21	20.77	31.98	4.2	16	0.9	22	12	0.7	84	89

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: AUGUST 1977

MAROX FLOWS AND CONCENTRATIONS

	********SECONDARY INFLUENT********						****RETURN SOLIDS****				*******MIXED LIQUOR********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
8/ 1	14.3	90	5.4	79	111	6.6	5.9	41	14000	10900	22	4290	3260	3.3	108	0.116	6.8
8/ 2	13.5	87	4.9	84	103	5.8	5.6	41	14800	11500	21	4600	3570	1.8	93	0.104	6.4
8/ 3	14.1	81	4.8	66	93	5.5	5.5	39	11800	9470	21	3370	2600	2.8	102	0.105	5.2
8/ 4	13.5	122	6.9	96	107	6.0	5.8	43	12600	10200	21	3200	2570	3.6	100	0.102	5.4
8/ 5	12.5	119	6.2	86	108	5.6	5.9	47	13800	10600	21	4150	3250	1.5	126	0.092	5.3
8/ 6	12.6	89	4.7	75	96	5.0	6.2	49	13300	10500	22	4200	3400	3.0	125	0.110	6.1
8/ 7	12.4	83	4.3	88	104	5.4	5.7	46	13200	10400	22	4140	3240	2.0	115	0.148	8.1
8/ 8	12.8	106	5.7	87	119	6.4	5.9	46	13500	10800	22	4100	3230	1.1	96	0.114	6.4
8/ 9	13.6	104	5.9	85	115	6.5	5.8	43	13200	10500	21	3660	2850	2.1	83	0.095	5.2
8/10	13.1	86	4.7	80	106	5.8	5.5	42	15400	12400	22	3800	3100	1.4	77	0.097	6.2
8/11	12.0	105	5.3	98	122	6.1	5.5	46	14400	11700	22	3880	3210	1.7	73	0.079	4.7
8/12	11.7	114	5.6	86	111	5.4	5.5	47	14600	12100	22	3750	2930	2.3	78	0.068	4.1
8/13	11.7	105	5.1	90	117	5.7	5.7	49	13600	10600	22	4160	3210	1.6	67	0.077	4.4
8/14	11.7	97	4.7	81	109	5.3	5.8	50	14200	11200	22	4500	3560	1.9	82	0.102	6.0
8/15	11.8	108	5.3	92	112	5.5	5.9	50	13900	10800	22	4760	3700	1.3	79	0.123	7.1
8/16	12.6	110	5.8	88	124	6.5	5.7	45	15000	11700	22	4200	3280	1.7	78	0.101	6.3
8/17	13.2	100	5.5	86	108	5.9	6.1	46	14600	11400	22	4330	3360	2.7	80	0.088	5.4
8/18	12.9	118	6.3	92	132	7.1	5.2	40	15200	11800	22	4030	3110	1.6	64	0.105	6.7
8/19	12.3	137	7.0	96	118	6.1	5.3	43	15400	11900	22	4310	3350	1.4	75	0.108	6.9
8/20	12.1	112	5.7	90	103	5.2	4.9	40	15000	11600	18	4480	3460	2.8	80	0.110	6.9
8/21	12.0	104	5.2	88	119	6.0	4.9	41	15000	11800	20	3840	2920	0.9	80	0.105	6.6
8/22	11.9	159	7.9	133	120	6.0	4.9	41	15400	12400	22	3980	3120	1.7	88	0.121	7.8
8/23	12.0	97	4.9	98	153	7.7	5.1	43	14800	11800	22	4040	3300	3.0	81	0.126	7.8
8/24	12.6	189	9.9	143	155	8.1	5.4	43	14000	11200	22	3860	3160	2.4	75	0.118	6.9
8/25	12.9	101	5.4	102	142	7.6	5.0	39	15000	11800	22	3830	3010	3.0	91	0.128	8.0
8/26	12.1	207	10.4	150	199	10.0	4.9	40	17000	13600	22	3460	2760	2.3	84	0.135	9.6
8/27	12.2	132	6.7	142	174	8.9	5.1	42	14200	11500	22	3740	2980	2.4	84	0.120	7.1
8/28	11.6	271	13.1	159	191	9.2	4.8	41	13800	11000	22	3700	2980	2.7	108	0.104	6.0
8/29	12.9	140	7.5	106	120	6.5	4.6	36	14400	11600	22	3580	2880	3.1	109	0.085	5.1
8/30	13.1	136	7.4	123	182	9.9	5.3	40	13900	11300	23	3840	3140	2.7	127	0.121	7.0
8/31	12.8	116	6.2	104	149	8.0	5.2	41	14600	11700	22	4000	3210	1.7	100	0.146	8.9
TOTAL	390.5		194.3			205.3	168.6									3.353	200.4
AVER.	12.6	120	6.3	99	127	6.6	5.4	43	14310	11347	22	3993	3152	2.2	91	0.108	6.5

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: AUGUST 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					********CLARIFIER********					********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M								BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT #7	DOB FT #9	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
8/ 1	142.6	1.60	0.70	-0.05	0.85	594	19.36	27.35	1.2	0.5	12.42	14.18	26.60	3.6	12	0.7	20	11	0.7	87	90
8/ 2	124.9	2.05	0.56	0.79	1.72	560	19.60	27.73	1.2	0.5	13.32	14.99	28.31	3.9	16	0.9	20	10	0.6	82	90
8/ 3	117.8	2.15	0.73	-0.86	0.17	585	15.00	20.85	1.8	0.2	9.76	12.76	22.52	3.4	24	1.4	22	14	0.8	70	85
8/ 4	129.7	-1.00	0.81	0.64	1.93	560	13.64	19.49	2.0	1.2	9.27	17.08	26.35	4.1	20	1.1	22	12	0.7	84	89
8/ 5	121.3	-1.00	0.60	0.25	1.46	519	16.37	24.10	1.3	1.0	12.02	15.87	27.89	4.7	13	0.7	20	9	0.5	89	92
8/ 6	108.6	2.20	0.51	0.46	1.47	523	16.70	24.92	1.5	1.0	12.16	15.90	28.06	4.2	10	0.5	20	8	0.4	89	92
8/ 7	115.8	2.06	0.57	0.27	1.15	515	16.20	23.65	1.0	0.5	11.99	12.76	24.75	2.8	15	0.8	18	10	0.5	82	90
8/ 8	136.8	1.91	0.68	-0.00	0.97	531	16.57	24.20	0.6	0.4	11.87	11.51	23.38	3.3	11	0.6	20	10	0.5	90	92
8/ 9	140.5	1.83	0.79	0.46	1.47	565	15.71	22.41	0.6	1.0	10.60	15.48	26.08	4.4	12	0.7	29	12	0.7	88	90
8/10	124.7	2.12	0.64	0.17	1.08	544	15.71	22.31	0.8	0.3	11.01	13.48	24.49	3.4	17	0.9	20	12	0.7	88	89
8/11	131.5	1.94	0.66	0.49	1.47	498	14.70	21.43	1.2	0.7	11.24	15.24	26.48	4.5	23	1.2	26	15	0.8	78	88
8/12	116.7	2.29	0.64	-0.49	0.68	486	13.85	20.36	1.3	0.1	10.86	13.78	24.64	4.9	19	0.9	24	13	0.6	83	88
8/13	123.0	2.14	0.61	0.21	1.21	486	15.36	22.85	1.6	0.1	12.05	13.77	25.82	5.2	13	0.6	20	12	0.6	88	90
8/14	114.6	2.25	0.52	0.89	1.87	486	16.62	24.86	1.7	0.2	13.03	15.03	28.06	4.2	14	0.7	20	11	0.5	86	90
8/15	118.7	2.18	0.51	0.31	1.38	490	17.73	26.59	1.1	0.3	13.79	13.12	26.91	3.4	18	0.9	24	11	0.5	83	90
8/16	140.3	2.21	0.69	0.17	1.30	523	16.70	24.26	1.1	0.1	12.16	13.47	25.64	3.2	30	1.6	30	27	1.4	73	78
8/17	128.1	2.08	0.61	0.43	1.48	548	18.04	26.38	1.3	0.3	12.54	14.45	26.99	4.2	19	1.0	27	13	0.7	81	88
8/18	152.9	1.78	0.79	0.09	1.11	535	16.41	23.02	1.1	0.3	11.67	14.35	26.02	3.3	23	1.2	24	16	0.9	81	88
8/19	130.4	2.00	0.62	0.40	1.69	511	16.73	23.94	1.1	0.4	12.48	14.89	27.37	3.5	18	0.9	23	12	0.6	87	90
8/20	111.9	2.28	0.52	1.45	2.68	502	17.11	24.04	1.7	1.0	12.97	16.62	31.59	3.9	24	1.2	24	12	0.6	79	88
8/21	128.3	1.88	0.70	-0.87	0.07	498	14.54	20.48	1.0	0.3	11.12	13.82	24.94	3.5	10	0.5	20	9	0.5	90	92
8/22	126.3	1.72	0.66	0.61	2.04	494	14.95	21.11	1.3	0.6	11.53	16.30	27.82	3.3	12	0.6	22	9	0.4	92	92
8/23	164.9	1.34	0.80	0.52	1.19	498	15.30	21.81	1.0	1.0	11.70	16.00	27.70	3.2	19	1.0	26	9	0.5	88	94
8/24	175.4	1.28	0.89	-0.23	1.06	523	15.35	21.93	0.8	1.8	11.18	17.06	28.24	3.7	14	0.7	26	9	0.5	93	94
8/25	164.5	1.37	0.88	0.63	1.42	535	15.60	21.64	0.5	2.1	11.09	18.28	29.37	3.4	13	0.7	22	13	0.7	87	91
8/26	216.3	0.98	1.26	0.30	1.40	502	13.21	18.57	1.5	1.5	10.02	22.27	32.29	3.1	16	0.8	20	11	0.6	92	94
8/27	190.7	1.06	1.03	-0.46	0.37	506	14.40	20.42	0.9	1.4	10.83	16.33	27.16	3.3	20	1.0	23	15	0.8	85	91
8/28	199.0	0.98	1.07	-1.03	0.45	482	13.55	19.15	0.7	1.0	10.72	13.97	24.69	3.8	10	0.5	17	8	0.4	96	96
8/29	139.0	1.53	0.77	0.04	1.31	535	14.58	19.78	0.1	2.1	10.37	16.23	26.60	4.5	14	0.8	20	10	0.5	90	92
8/30	214.2	0.99	1.09	0.19	1.00	544	15.88	22.30	0.3	2.2	11.12	16.62	27.74	3.5	18	1.0	24	15	0.8	87	92
8/31	171.3	1.35	0.86	0.53	1.41	531	16.16	22.73	0.2	2.0	11.58	16.45	28.04	2.9	15	0.8	26	16	0.9	87	89
TOTAL											358.47	474.02	832.50			26.9			19.7		
AVER.	142.7	1.78	0.73	0.20	1.25	523	15.86	22.73	1.1	0.9	11.56	15.29	26.85	3.7	17	0.9	23	12	0.6	85	90

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: SEPTEMBER 1977

MAROX FLOWS AND CONCENTRATIONS

	*********SECONDARY INFLUENT*********						****RETURN SOLIDS****				*******MIXED LIQUOR*********					***WASTE***	
DATE	FLOW MGD	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	FLOW MGD	%	SS MG/L	VSS MG/L	TEMP C	SS MG/L	VSS MG/L	DO MG/L	SVI	FLOW MGD	SS TONS
9/ 1	12.9	129	6.9	107	117	6.3	4.6	37	13400	10900	21	3730	2980	2.9	95	0.144	8.0
9/ 2	12.4	136	7.0	133	172	8.9	5.1	41	13500	11700	20	4100	3280	2.3	105	0.131	7.4
9/ 3	12.5	138	7.2	97	124	6.5	5.1	41	13300	11300	20	3920	3120	2.7	113	0.127	7.0
9/ 4	12.0	90	4.5	76	97	4.9	4.9	41	14000	11400	21	3880	3110	2.4	115	0.136	7.9
9/ 5	12.4	106	5.5	86	145	7.5	4.9	40	14800	12200	22	3280	2680	2.8	119	0.311	19.2
9/ 6	12.1	115	5.8	122	162	8.2	4.8	40	12700	10400	22	3290	2710	2.2	120	0.079	4.2
9/ 7	8.7	96	3.5	106	145	5.3	3.4	39	12800	10500	23	3460	2820	2.9	94	0.056	3.0
TOTAL	83.0		40.4			47.4	33.0									0.984	56.8
AVER.	11.9	116	5.8	104	137	6.8	4.7	40	13500	11200	21	3666	2957	2.6	109	0.141	8.1

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

10/18/77 METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1 PERIOD: SEPTEMBER 1977

MAROX LOADING, INVENTORY AND PERFORMANCE

	********AERATION BASIN********					********CLARIFIER*********					********INVENTORY********				***SECONDARY EFFLUENT***					*% REM*	
			F/M								BASIN	CLAR	TOTAL								
DATE	# BOD /KCF	#O2/ #BODR	BOD/ MLVSS	BIOSYNTHESIS NET	GROSS	OVERFLOW G/SF/DY	FLUX #/SF/DAY Q	Q+R	DOB FT #7	DOB FT #9	SS TONS	SS TONS	SS TONS	SRT DAYS	SS MG/L	SS TONS	TOC MG/L	BOD MG/L	BOD TONS	SS	BOD
9/ 1	135.6	1.84	0.73	0.03	1.32	535	15.19	20.84	0.7	1.5	10.80	15.10	25.90	2.8	22	1.2	23	17	0.9	83	85
9/ 2	191.6	1.27	0.94	0.23	1.11	515	16.05	22.65	0.3	1.7	11.87	14.60	26.47	3.2	18	0.9	24	17	0.9	87	90
9/ 3	139.2	1.82	0.72	0.08	1.32	519	15.47	21.78	0.8	1.4	11.35	14.99	26.34	3.4	14	0.7	21	13	0.7	90	90
9/ 4	104.6	2.43	0.54	0.85	1.92	498	14.70	20.70	1.0	0.8	11.24	14.50	25.73	3.0	15	0.8	19	13	0.7	83	87
9/ 5	161.5	1.51	0.97	1.53	2.33	515	12.84	17.91	0.3	0.6	9.50	12.28	21.78	1.1	15	0.8	20	12	0.6	86	92
9/ 6	176.1	-1.00	1.04	-0.26	0.53	502	12.57	17.55	0.3	0.7	9.53	10.83	20.35	3.8	22	1.1	25	17	0.9	81	90
9/ 7	113.3	-1.00	0.64	0.18	0.90	361	9.50	13.21	0.1	1.0	10.02	11.20	21.22	6.1	13	0.5	24	13	0.5	86	91
TOTAL											74.31	93.49	167.80			6.0			5.1		
AVER.	146.0	1.77	0.80	0.38	1.35	492	13.76	19.23	0.5	1.1	10.62	13.36	23.97	3.3	17	0.9	22	15	0.7	85	89

-1 INDICATES ABSENCE OF DATA REQUIRED FOR CALCULATIONS

APPENDIX B

FILAMENTOUS INVESTIGATIONS: REPORTS OF DR. W. O. PIPES

Appendix B is a collection of correspondence from Dr. Wesley O. Pipes to the FMC Corporation concerning the investigation and attempts at identification and control of filamentous organisms in the oxygen system activated sludge.

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RECEIVED AT

January 17, 1977

Mr. Richard Weber
FMC Corporation
3999 S. Mariposa
Englewood, Colorado 80110

Dear Mr. Weber:

This letter constitutes a report of my visit to your office and to your demonstration at the Metropolitan Denver Sanitary District North Plant on Jan. 10, 1977 and my subsequent review of the data supplied to me and the samples I collected.

From the discussions with you, Dr. Hise and Mr. Parker and the review of the data the following points were established:

1. The SVI in the Marox demonstration process was less than 100 ml/gm during May, June, and the first half of July, 1977.
2. Since July 15, 1977 the SVI in the Marox process has shown a tendency to rise into the 200 to 300 ml/gm range or even higher. The process has really never been stabilized during the last six months despite four attempts to start the process fresh by dumping all the mixed liquor.
3. The problem of maintaining satisfactory effluent suspended solids and BOD concentrations is compounded by the fact that the overflow rate on the secondary settling tank is slightly high. When the sludge blanket rises, there is a good chance of solids being carried out due to the high overflow rate.
4. The SVI measurements are not consistant but vary with the mixed liquor suspended solids concentrations. The lower afternoon SVI measurements during the period since Dec. 28, 1976 are all associated with lower afternoon mixed liquor suspended solids concentrations.
5. The Metropolitan Denver conventional air system may be having essentially the same problem as the Marox system, but there are not sufficient data to demonstrate this.

Microscopic examination of samples at the Metropolitan Denver plant resulted in the following observations:

1. The float material from the Marox system is not greatly different from the mixed liquor and does not contain large quantities of actinomycetes. However, the float material

from the Unox system does contain many actinomycete colonies.

2. The Marox system mixed liquor contains two types of filamentous microorganisms. One type appears as a series of rod-shaped cells about 1.5 µm in diameter. It was present in the Marox mixed liquor during May and June 1976 and is still present. The other type is more slender and appears as a continuous filament.

3. Both types are also present in the air system mixed liquor.

4. Both types are also present in the influent. Actinomycete colonies were also seen in the influent, but they were judged to be derived from the filtrate from the Unox sludge.

5. The activated sludges in both the Marox and air systems appear to be poorly flocculated.

I prepared streak plates on corn meal agar and glucose-peptone-yeast extract agar of the secondary influent, air mixed liquor, and Marox mixed liquor. I also brought back samples of these materials for further examination. My laboratory results, so far, are as follows:

1. Filamentous bacteria did not develop on the streak plates. However, I have the filamentous bacteria growing in a liquid enrichment culture. I may be able to isolate them in the next few weeks.

2. The streak plates did develop unusually large numbers of fungi. The dominant types are those which produce arthrospores (Geotrichun, Oidiodendron, and Trichosporon). I do have these organisms in pure culture.

3. The arthrosporic fungi could give the appearance of chains of rod-shaped cells in liquid culture; thus, these fungi could account for the filamentous organisms which have been present in the mixed luqour since last May.

4. The arthrosporic fungi are also present in the secondary influent.

I have encountered arthrosporic fungi as nuisance organisms in activated sludge twice before. They are extremely difficult to get rid of, but the activated sludge system can be operated to give satisfactory performance even when they are present. The other filamentous organism may be even more of a problem, but I don't want to speculate further until I can find out more about it.

I recommend that we undertake a program to accomplish the following objectives:

1. Operate the system to give satisfactory performance in spite of the high SVI and in spite of the poor flocculation.

2. Determine if the same problem exists in the air system as in the Marox system.

3. Determine if the secondary influent is the primary source of filamentous organisms.

4. Find a technique for improving the flocculation of the activated sludge.

5. Find a method of reducing the SVI.

The first thing we need is a method of measuring SVI which gives reproducible results and which gives an SVI value independent of the mixed liquor suspended solids concentration. I recommend using a one liter cylinder with a stirrer operated at one rpm or less. I also recommend that you acquire equipment so that four settled volume tests can be run simultaneously and that SVI versus suspended solids concentration curves be developed for both the Marox and air sludges. I discussed this test procedure with Dr. Hise and Mr. Parker when I was out there last Monday. If it can be shown that the SVI versus suspended solids concentration curves are the same for both the Marox and air systems, this would go a long way toward demonstrating that the problems are the same. In any case we need to get consistant SVI values to deal with the problem in the Marox system.

We need to have a measure of how well flocculated the sludges are. The only reasonable measure of flocculation that anyone has come up with so far is the supernatent suspended solids from the settled volume test. However, mixed liquor suspended solids concentration has an influent on the supernatent suspended solids. After the SVI versus suspended solids curve has been determined, pick a solids concentration (about 3000 mg/l) which gives a consistant settled volume and use it as a standard solids concentration for determining both settled volume and supernatent suspended solids. After several days of supernatent suspended solids data have been collected plot these values versus the respective effluent suspended solids. There should be a linear proportionality between the two values if the secondary settling tank is being operated properly.

In order to stabilize operation of the system I recommend that the secondary influent be introduced at a constant rate (the large daily fluctuations in the aeration tank suspended solids may be part of the problem). If it is impossible to obtain a constant influent rate, adjust the return sludge flow rate in proportion to the influent flow rate. The mixed liquor suspended solids should be

$$\text{MLSS} = \frac{R}{Q + R} \text{ (RAS)}$$

Have your operator make this calculation each day and check it against the measured MLSS. It will help him understand your operational objectives.

I recommend that the return sludge flow rate be made equal to the influent flow rate (R=Q). Have the operator calculate a solids balance on the secondary settling tank each day (pounds of solids in = pounds of solids out) and measure the height of the sludge blanket each day. Once the sludge blanket is gone and the solids balance works (within 10%) reduce the return sludge rate slowly. I recommend operating at R = 0.9 Q for a few days to see how the system responds, then going to R = 0.8 Q for a few days, etc. When the sludge blanket starts to build up again do not reduce R any further. Try to hold the sludge blanket at least two feet below the overflow weirs.

I recommend that you allow the solids to build up in the system and try to operate between 5000 and 6000 mg/l in the aeration tank. This will reduce the F/M ratio which should improve flocculation. It will also increase the SRT which could encourage the growth of actinomycetes in your sludge. Continue the periodic microscopic examination of your sludge. If the actinomycetes show up reduce the SRT even if it requires increasing the F/M ratio.

I suggest that you send me weekly data summaries for my review. If an operating problem arises suddenly, you can call me and I will respond as best I can on the telephone.

I believe that we need to isolate and identify the other filamentous organism from your sludge in order to determine if the air system has the same problem and if the source of the organism is the secondary influent. I will be working with my enrichment cultures for the next couple of weeks to see what I can isolate. If I am able to isolate the organism, I will need to get additional samples to demonstrate that it really is the organism in your system. If I don't isolate the organism, I will need additional samples for trying different isolation techniques.

The arthrosporic fungi need to be investigated further. There are techniques for obtaining reasonably precise counts of these organisms in wastewater and in sludge. However, this would require a significant amount of laboratory time. I could get a student here and train him for that type of work, but, if the laboratory work were done here, the expense of transporting the samples would be rather large. It might be more reasonable for you to get a laboratory technician whom I could train to work out there.

These recommendations and suggestions should give you a good deal to think about and I expect that you will have several questions. I will be expecting a response from you after you have had time to consider all these points. Looking ahead, it occurs to me that Monday, Jan. 31, might be a suitable date for me to make another visit to Denver so that we could review the progress and I could obtain additional samples.

Sincerely,

Wesley O Pipes

W. O. Pipes
Betz Professor of Ecology
Department of Biological Sciences

WOP/sls

WESLEY O. PIPES, PH.D.
37 SHADY HILL ROAD
MEDIA, PENNSYLVANIA 19063
—
(215) LO 6-2446

A
RECEIVED AT
[illegible] CO.

February 1, 1977

Mr. Richard B. Weber
3999 South Mariposa Street
Englewood, Colorado 80110

Dear Mr. Weber:

Enclosed is my report on examination of the samples which were sent to me during January. The fungus counts in the system are high but apparently not high enough to indicate that fungi are a major part of the problem. The filamentous bacteria grow very slowly or not at all in the enrichment cultures I have tried so far. It appears that they will be difficult to isolate and identify them but I believe that we should continue to try in order to show that the same problems exist in both the air and Marox systems and to devise a ready-made solution in case this problem ever occurs in another Marox system.

In this type of situation it is important to be able to correlate the laboratory observations with the operating data and with experiments with sludge samples. I would like to have the opportunity to analyze the operating data for January for both the air and Marox systems. Once your laboratory personnel are set up to run settling tests at different solids concentrations, as I recommended in my letter of Jan. 17, 1977, and we can get some data to determine the similarity of settling characteristics of the air and Marox sludges, I will be able to recommend some laboratory experiments which can be used to test some possible solutions to the bulking problem. I have always found it expedient to try out ideas in laboratory tests before trying them in the plant because a variety of ideas can be tried out at the same time without running the risk of upsetting plant performance.

There are no obvious simple solutions to this problem and it may take some time and effort to find and demonstrate a solution. It is possible that we may stumble across a simple solution such as just reducing the time the sludge is out of the aeration tank; however, at this point we can't count on that. We really need operating data for some extended period when the operating conditions are not changed frequently and then a careful trial of possible solutions suggested by knowledge of the nature of the filamentous organisms and/or by laboratory tests with sludge samples.

Sincerely,

W. O. Pipes

W. O. Pipes, Ph.D.
Betz Professor of Ecology

FEB 1977
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FMC
[illegible] CO.

W. O. Pipes

Jan. 31, 1977

FMC-DENVER PROJECT

Examination of Samples for Filamentous Microorganisms

Introduction

This report covers the examination of samples collected from the Metro Denver North plant on Jan. 10, Jan. 19, Jan. 25, and Jan. 27, 1977. There is a demonstration Marox oxygen activated sludge system operating at this plant. Both the air and the Marox systems have had operational difficulties over the past six months apparently due to poorly flocculated activated sludge and a growth of excessive numbers of filamentous microorganisms which causes high SVI values. The objectives of these examinations were to determine the indentities of the filamentous microorganisms and obtain some clues to the nature of the problem so that potential solutions can be developed.

Samples

Jan. 10, 1977 Microscopic examination of the air and Marox mixed liquor samples showed that the floc particles in both systems were loose and open textured. Two types of filamentous microorganisms were seen in both mixed liquor samples. Some filamentous microorganisms were seen in the secondary influent sample.

Both mixed liquor samples and the secondary influent sample were streaked on glucose-peptone-yeast extract agar (GPY) and on corn meal agar. Filamentous bacteria did not grow on these plates; however, several fungus colonies developed. Many of the fungi produced arthrospores or blastospores or both. On the four secondary influent streak plates a total of 15 fungus colonies developed of which 8 produced arthrospores, 3 produced blastospores, and 2 developed both arthrospores and blastospores. On the four air mixed liquor streak plates a total of 25 fungus colonies developed of which 6 produced arthrospores, 12 produced blastospores and 2 produced both. On the four Marox mixed liquor streak plates a total of 19 fungus colonies developed of which 4 produced arthrospores, 4 produced blastospores, and 2 produced both. Although these fungus counts can not be related to the volume of liquid which contained them, they are unusually high numbers of fungus colonies for streak plates. Arthrosporic fungi can sometimes look very much like filamentous bacteria when growing in a liquid. Thus, it was decided that future samples should be examined for fungus colony counts.

The two types of filamentous bacteria from the mixed liquor samples were observed to be growing on GPY plates which were flooded with 4 ml of mixed liquor each. Many other microorganisms were also growing in these cultures.

Jan. 19, 1977 Samples of air mixed liquor and Marox mixed liquor collected on Jan. 19 were received that evening and examined the following day. The floc particles were still loose and open textured. Both types of filamentous microorganisms were still present. A few short chains of what could be arthrospores were seen in the Marox mixed liquor but not in the air system mixed liquor. Clumps of cells which could be blastospores were seen in both mixed liquor samples.

Pour plates of serial dilutions; 0.1, 0.01, 0.001, and 0.0001 ml per plate; were made of the two mixed liquor samples on GPY agar. Microscopic counts of floc particles in the agar and of floc particles developing fungus mycelia were made on random fields after four days of incubation at 20°C. The purpose of these counts was to determine the faction of the floc particles which developed mycelia and thus to test the hypothesis that most of the floc particles were developing around fungus mycelia. In the Marox mixed liquor 1.3% of the floc particles developed mycelia and in the air system mixed liquor 0.4% of the floc particles developed mycelia. From this, the hypothesis was rejected.

Total counts of fungus colonies developing on the pour plates were made.

In the air system mixed liquor, the fungus colony count was 1500 per ml of which 500 had arthrospores and 900 had blastospores. In the Marox mixed liquor, the fungus colony count was 900 per ml of which 300 had arthrospores and 600 had blastospores. Pour plates using GPY agar is not the best method of obtaining fungus colony counts, so any conclusions about the numbers and role of the fungi in the systems were deferred until after examination of additional samples.

Liquid enrichment cultures were made up in GPY broth and lactate-glycerol broth and innoculated with mixed liquor from the Marox and air systems. These enrichment cultures were aerated and incubated at 20°C. Microscopic examination after four days of incubation showed that the filamentous bacteria were not growing in these cultures.

Microscopic examination of the mixed liquor samples on Jan. 24, after they had been sitting at room temperature for five days without aeration showed that the two types of filamentous microorganisms were growing more than the other sludge organisms. The larger organism had formed filaments up to 300 um long. This organism is greater than 1 μm in diameter and forms a continuous tube, not divided into cells, having occasional dark inclusions. The other filamentous organism is less than 1 μm in diameter, has many dark inclusions, and forms short filaments (about 40 μm long) sometimes in a rosette formation. From the observation that these organisms are growing in the anaerated mixed liquor samples, it was hypothesized that they are microaerophylic. The dark inclusions could be sulfur deposits.

Jan. 25, 1977 Samples of air mixed liquor, Marox mixed liquor, and raw sewage collected around noon were received at 7:00 p.m. and examined that evening. Three samples of raw sewage were received; labeled Delganey structure, Gibville Main, and Broadway Relief Main. The sample from the Delganey structure is a mixture of sewage from four interceptors two of which are the Gibville Main and the Broadway Relief Main.

Microscopic examination of the mixed liquor showed that both types of filamentous organisms were still present in both samples. The Marox mixed liquor appeared to be more poorly flocculated and the air mixed liquor better flocculated than previous samples.

Spread plates were made of serial dilutions; 0.1, 0.01, 0.001, and 0.0001 ml per plate; on Cooke's Rose Bengal Agar with chlorotetrocycline. This medium is the best known for isolation of fungi from water and wastewater. The fungus colony counts at four days of incubation at 20°C are presented in Table I.

TABLE I

Fungus Colony Counts (per ml) on Jan. 25 Samples

Sample	Counts			
	Total	Colonies with Arthrospores	Colonies with Blastospores	Other Fungus Colonies
Air ML	2100		1300	800
Marox ML	1600	400	600	600
Delganey	1000		800	200
Gibville	300	100	200	
Broadway	700	100	400	200

These counts are somewhat higher than are usually found in raw sewage and mixed liquor samples. The question of their significance in the system is deferred for the discussion below.

In an attempt to find a suitable enrichment techniques for the filamentous organisms seen in the mixed liquor samples, liquid cultures were made up using 1) sodium acetate, 2) sodium acetate plus sodium sulfide, 3) sodium acetate plus peptone, and 4) glucose, peptone, and sodium sulfide. The cultures were incubated at 20°C and not aerated. The two types of filamentous microorganisms grew in all four enrichment media but only in the cultures with glucose, peptone, and sulfide did they grow more than in the unenriched, unaerated mixed liquor.

Heavy streaks of mixed liquor were placed on acetate-sulfide agar and these plates were incubated in air at 20°C. The filamentous microorganisms grew for two days on these plates but other microorganisms grew more vigorously and after four days the filaments were breaking up.

Two hundred ml of sewage was placed in the bottom of a dessicator and 1 gm of dextrose, 1 gm of peptone, and 500 mg of M_g SO_4 were added to stimulate the production of H_2 S. Heavy streaks of mixed liquor were placed on GPY agar and on acetate sulfide agar and these plates were incubated in the dessicator for four days. The filamentous microorganisms grew more vigorously on these plates than on the acetate-sulfide plates incubated in air. However, several protozoans developed on these plates and spread the other bacteria to the extent that the isolation of the filamentous microorganisms is impossible.

Jan. 27, 1977 Samples collected in the morning were received at 5:30 p.m. and examined that evening. The samples were air mixed liquor, Marox mixed liquor, secondary influent and raw sewage.

The microscopic examination showed the mixed liquor samples to be quite similar to those of Jan. 25. Both types of filamentous microorganisms were still present.

Spread plates were made of serial dilutions; 0.1, 0.01, 0.001, and 0.0001 ml per plate; on Cooke's Rose Bengal Agar with chlorotetracycline. The fungus colony counts at four days of incubation are presented in Table II.

TABLE II

Fungus Colony Counts (per ml) on Jan. 27 Samples

Sample	Counts			
	Total	Colonies with Arthrospores	Colonies with Blastospores	Other Fungus Colonies
Air ML	4300	400	2700	1200
Marox ML	5200	300	3100	1800
Secondary Influent	1200	100	400	700
Raw Sewage	300	100		200

Discussion

Fungi The loose, open texture of the floc particles suggested that the floc might be fromed by bacterial cells adhering to the outside of fungus mycelia. The counts made on the pour plates of the Jan. 19 samples shows that this is not the case. The vast majority of the floc particles do not contain fungi. Some other explanation must be sought for the poor flocculation.

The usual range for fungus colony counts both on raw sewage and on mixed liquor samples is 10 to 100 colonies per ml. I have previously seen mixed liquor samples which had obvious fungus mycelial mats and in which the fungus colony counts were in the range of 10,000 to 100,000 per ml. In those cases the fungi clearly were associated with poor flocculation and a high SVI.

In this case the fungus colony counts in the raw wastewater are in the range of 100 to 1,000 per ml and in the mixed liquor samples are in the range of 1,000 to 10,000 per ml. The only count made on the secondary influent showed more fungus colonies than the influent. Except for the samples of Jan. 27 the majority of the fungi are those which produce blastospores. The blastosporic fungi are commonly called yeast and, although they are not uncommon in sewage, it is a bit unusual to find them making up over half of the fungi present.

Whether the fungi are growing in the aeration tank or not is not clear from these data. The fungus colony counts in the mixed liquor are almost 10 times higher than those of the raw sewage but the solids in the mixed liquor should be about 10 times higher than in the raw sewage. Although only one fungus colony count was made on the secondary influent the results are suggestive of some source of fungus growth within the plant. There is no other apparent reason for a higher fungus count in the secondary influent than in the raw wastewater.

At this point, it is apparent that the filamentous microorganisms in the mixed liquor are not fungi. Further investigation of fungi in the activated sludge system does not seem warranted except for investigation of a possible source of fungi somewhere between the raw sewage and the secondary influent.

Bacteria The two types of filamentous microorganisms in the mixed liquor are bacteria. They do not grow on an agar medium with a simple substrate and the usual array of growth factors. They are not Sphaerotilus natans, Bacillus cereus, Vitreoscilla, or Cytophaga. They do not form true branches; thus, they are not any of the actinomycetes. They seem to be stimulated by sulfide ion and thus could belong in the Beggiatoa - Thiothrix group. However, this awaits further confirmation.

The filamentous organisms appear to be microaerophylic because they grow more vigorously in unaerated cultures. Why microaerophylic organisms should be growing in an oxygen activated sludge system is rather puzzeling. The only apparent reason is that there must be periods of anaerobic conditions in the secondary settling tank and the return sludge lines where they have an opportunity to grow.

Recommendations

1. In seeking a solution to a case of filamentous bulking when

the causative organisms can not be isolated immediately, it is very important to analyze the operating data to determine how the activated sludge reacts under different conditions. I recommend that the operating data for the month of January for both the Marox and air systems be supplied to me for my analysis.

2. It appears that the sludges in both the air system and the Marox system are similar. The tests to demonstrate that they do have similar settling and flocculation characteristics should be carried out as soon as possible. Please refer to my letter of Jan. 17.

3. The entire flow diagram for the Metro Denver North Plant should be analyzed to determine if there is a potential source of fungi between the raw sewage and secondary influent.

4. From the information gleaned about the filamentous microorganisms in the mixed liquor, it appears that one possible solution to the high sludge volume index could be to reduce the amount of time that the sludge is held in the secondary settling tank and the return sludge lines.

5. The efforts to isolate and identify the filamentous microorganisms in the sludge should continue. Identification of these organisms is essential for demonstrating that the problem in the Marox system is the same as in the air system and for development of a ready-made solution for the problem if it ever is encountered in other Marox systems.

March 16, 1977

Mr. Richard B. Weber
Operations Manager
Marox Diffusion Systems
FMC Corporation
3999 South Mariposa Street
Englewood, Colorado 80110

Dear Mr. Weber:

Enclosed is a report on my examination of the samples of March 10, 1977. It is clear that the filamentous organisms present now are different from those present in January. The air systems are growing an organism tentatively identified as Sphaerotilus natans which does not appear to be growing in the Marox system. The fact that Sphaerotilus is growing in the air system but not in the parallel Marox system could be quite significant if it continues.

The Marox mixed liquor contains large numbers of short, irregularly bent filaments. I have had no success in trying to grow this organism. It could be the same organism which was present in the Marox mixed liquor during June last year if I remember the stained slides from that period properly. The filaments are short enough that they may not interfer very much with settling and compaction.

Sincerely,

W. O. Pipes, Ph.D.
Betz Professor of Ecology

WOP/sls
enclosure

cc: Dr. Ralph Hise

FMC - DENVER PROJECT

EXAMINATION OF MARCH 10 SAMPLES

Four samples were received on the evening of March 10, 1977; namely, Marox mixed liquor, air mixed liquor from area 2, air mixed liquor from area 4, and secondary influent.

Microscopic Examination

The Marox mixed liquor was poorly flocculated with many free bacterial cells and the floc particles were loose, network-like structures. Many free swimming and stalked ciliates were present. These protozoa are usually associated with a well flocculated sludge and probably indicate that the flocculation will improve. One filamentous organism was present in large numbers. It is greater than 1 µm in diameter and forms short, irregularly bent filaments with dark inclusions. It is an organism which was not present in any of the samples examined during January. No other filamentous organisms were observed.

The Marox mixed liquor was reexamined after sitting unaerated for four days. The short irregularly bent filaments were still present but gave no appearance of having grown. A much longer, more slender filamentous organism had appeared. It appeared to be a sheathed bacterium.

The air mixed liquor from area 2 was somewhat better flocculated than the Marox mixed liquor but not well flocculated. A variety of protozoa were seen but none in large numbers. Two filamentous organisms were seen. The short, irregularly bent filaments seen in the Marox mixed liquor were present in small numbers. The dominant filamentous organism was less than 1 µm in diameter and appeared to be a sheathed bacterium. Reexamination of the sample after four days without aeration showed that the longer, more slender, filamentous organism had grown and many more filaments were present.

The air mixed liquor from area 4 was better flocculated than the other two samples. However, it had many free swimming flagellated organisms which are usually indicative of poor flocculation and low dissolved oxygen concentration. Both types of filamentous organisms were present. After the sample had been left four days without aeration the longer, more slender filamentous organism had grown and many more filaments were present. Shorter filaments of the more slender organism showed motility.

The secondary influent sample showed both types of organisms present in good numbers. This is probably due to some recirculation of material from the activated sludge.

Sludge Test

The lysozyme - detergent test was performed on all three sludge samples on March 11, 1977. The longer, more slender organism is definately a sheathed bacterium, probably *Sphaerotilus natans*. The irregularly bent filaments were dissolved completely.

Cultures

Spread plates were made of serial dilutions (0.1, 0.01, and 0.001 ml per plate) on Cooke's rose bengal agar, GPY agar, AcS agar, and tryptacase soy agar (TSA). The fungus colony counts were in the same range as the January counts. It was not possible to obtain counts of filamentous bacterial colonies due to overgrowth of the plates by fungi and protozoa.

Streak plates were made on GPY, AcS, and TSA media. The short, irregularly bent filaments started to grow on the AcS plates but were overgrown by other bacteria in four days. Colonies of the sheathed bacterium were isolated from TSA plates.

Summary

In terms of operational effect, the most disturbing feature of the Marox mixed liquor is the poor flocculation. This may be a feature of the start-up process and the flocculation could improve greatly. However, if the flocculation does not improve the F:M ratio should be reduced.

The sheathed filamentous bacterium in the air mixed liquor is tentatively identified as Sphaerotilus natans. It definately was not present in the samples examined during January. The fact that it is growing in the air systems but not in the Marox system could be extremely significant. This needs more documentation.

The irregularly bent, filamentous organism which dominates the Marox mixed liquor appears to be different from the two organisms which were present in January. It could correspond to one of the filamentous organisms seen on the stained slides from last summer. I have no information as to why it would be showing up again at this time.

Department of Biological Sciences
(215) 895-2624

drexel university · philadelphia 19104 · 215-895-2000

March 24, 1977

Mr. Richard B. Weber
Operations Manager
Marox Diffusion Systems
FMC Corporation
3999 South Mariposa Street
Englewood, Colorado 80110

Dear Mr. Weber:

This will complete my report on the examination of the samples received on February 23, 1977. You may recall that in my report of March 2, 1977 I mentioned that I had made pour plates with nutrient agar to obtain actinomycete counts but that it would take four weeks for the colonies to develop.

The Englewood sewage had an actinomycete count of 10 per ml. Of the two samples from the Metro Denver North Plant, the air mixed liquor had a count of 300 per ml and the Marox Pilot Plant had a count of 3000 per ml. These counts are not high enough to indicate an operational problem, however, they do indicate the potential for developing an actinomycete problem. Keeping the sludge residence time in the activated sludge systems to less than 12 days should prevent the problem from developing.

Sincerely,

Wesley O Pipes
W. O. Pipes, Ph.D.
Betz Professor of Ecology

WOP/sls

cc: Dr. Ralph E. Hise

Department of Biological Sciences
(215) 895-2624

drexel university · philadelphia 19104 · 215-895-2000

July 19, 1977

Mr. Richard B. Weber
Operations Manager
Marox Diffusion Systems
FMC Corporation
3999 South Mariposa Street
Englewood, Colorado 80110

Dear Mr. Weber:

Enclosed is a report on my examination of the samples which were sent to me on June 16, 1977. The Marox mixed liquor at that time was in better condition than the air mixed liquor but I did not find anything unusual about the microbiology of either sample.

I am also enclosing a summary of my findings on all the samples for the January-June period. The summary describes some culture work which we did during March and April and which had not been previously reported to you. I believe that the filamentous bacterium which was causing the problem last winter is an acid-producing, sheathed organism which has not previously been described. However, there is another filamentous bacterium which is still present in both systems and we never have been able to do any culture work with it. Thus, I am not able to reach any firm conclusions.

Sincerely,

Wesley O. Pipes

Wesley O. Pipes, Ph.D.
Betz Professor of Ecology

WOP/sls
enclosure
cc: Dr. Ralph E. Hise

JUL 1977
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Samples of June 16, 1977

On June 16, samples from the Metro Denver North plant were received. The samples were from the Marox system basin 11, the air system basin 10, and the secondary influent flowing into basin 11. Spread plates of serial dilutions (0.1, 0.01, 0.001, and 0.0001 ml per plate) were made on Cooke's Rose Bengal agar, on glucose-peptone-yeast extract (GPY) agar, on acetate-sulfide (AcS), and on trypticase soy (TS) agar. Heavy streaks of mixed liquor samples were made on GPY agar and AcS agar. All plates were incubated at 20°C.

An extra sample consisting of algae from the secondary settling tank was also received. This sample was examined microscopically and then streaked on GPY and AcS agar plates.

Microscopic Examination

The Marox mixed liquor sample showed a well flocculated sludge but the particles were small and stringy (tassel-like). Many free swimming and stalked ciliates were seen indicating a "well-oxidized" sludge. Only one type of filamentous organism was seen. It was apparent as the short, irregularly bent filament with dark inclusions which is more than one micrometer in diameter and which has been seen in all the mixed liquor samples from this plant. It apparently does not interfere with the settling characteristics of the sludge.

The mixed liquor from the air system showed a loose textured sludge with very small, stringy particles. The sludge was highly filamentous and the filaments appear to be the same type as seen in the Marox system. Only a few ciliated protozoa were seen.

The secondary influent samples had only a small amount of suspended material in it. A few filamentous bacteria of the same type seen in the mixed liquor were present. The filaments in the secondary influent are much, much longer than those in the mixed liquor.

The algae from the secondary settling tank consisted of very long filaments of Ulothrix, many green flogellated algae of the genus Euglena, and many desmids of the genus Closterium. These are common types of algae often found around sewage outfalls. Ulothrix grows attached to surfaces and forms a microhabitat which provides conditions suitable for the other algae. Many protozoa were also associated with the algae as were filamentous bacteria of the type seen in the mixed liquor. A few large filaments showed numerous dark inclusions and a definate gliding motility. They are definately Beggiatoa but they were not found in the mixed liquor samples. Streak plates were made on GPY agar and AcS agar in an attempt to isolate the Beggiatoa.

Streak Plates

The filamentous bacterium seen in the two mixed liquor samples and in the secondary influent did not grow on any of the streak plates. This is consistant with previous results. One filamentous bacterium was isolated from the Marox mixed liquor. It was found to be a gram negative spore-former and its morphology is consistant with that of *Bacillus cereus*. It is clearly not the filamentous organism growing in the sludge.

The *Beggiatoa* from the sample of algae from the surface of the secondary settling tank grew slowly on AcS agar. However, it was not isolated.

Fungus Counts

The fungus colony counts on Cooke's Rose Bengal Agar made after four days of incubation are given in Table I. These counts are quite comparable with the fungus found on samples obtained during the winter. They are somewhat higher than normal for sewage and mixed liquor samples but apparently the fungi in this case are not associated with deterioration of the settling properties of the sludge.

TABLE I

Fungus Colony Counts (per ml) on June 16 Samples

Sample	Total	Colonies with Arthrospores	Colonies with Blastospores	Other Fungus Colonies
Air ML	3,700	700	200	2,800
Marox ML	2,400	1,200	200	1,000
Secondary Influent	300		100	200

Actinomycete Counts

Actinomycete counts were made on the TS plates after 28 days of incubation. The actinomycete count on the secondary influent was 70 per ml, on the air mixed liquor 580 per ml and on the Marox mixed liquor 1,100 per ml. These counts are not high enough to indicate an operating problem.

Summary

The June 16, 1977 samples showed a well flocculated sludge in the Marox system but a poorly flocculated, filamentous sludge in the air system. The filamentous bacterium in both systems is the short, irregularly branched organism which has been seen in all samples examined from this plant. Fungi and actinomycetes are also present but in relatively small numbers.

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Summary of Samples Examined

January - June 1977

Introduction

This report summarizes the information obtained about the microbiology of the air activated sludge and Marox systems at the Metro Denver North plant for the period January through June 1977. Both systems have had operation difficulties from time to time due to poor flocculation and a growth of excessive numbers of filamentous organisms which cause excessively high SVI values. The Marox system is a demonstration project operating in one basin of the activated sludge plant in parallel with the air system. A pilot plant Marox system was also operated to provide additional information for comparison purposes.

Samples

Samples of mixed liquor from the air activated sludge system and the Marox system were obtained on January 10, 19, 25, and 27, February 23, March 10, and June 16. The Marox sample on February 23 was from the pilot plant. Secondary influent samples were examined on January 27 and June 16. Raw sewage samples were examined on January 25 and January 27. Raw Englewood sewage samples were examined on February 23.

Filamentous Bacteria

One type of filamentous bacterium was seen in all mixed liquor samples. It is a short, irregularly bent organism with dark inclusions. It is between one and two micrometers in diameter and is not divided into cells. We had no success attempting to grow this organism in the laboratory dispite trying several different media and a variety of cultural conditions. When the mixed liquor samples are left unaerated for several days it grows forming longer filaments. A lysozyme-detergent test failed to reveal the presence of a sheath and it reacted negatively to a sulfur deposition test. Thus, it is neither Sphaerotilus nor Beggiatoa. It is present in the raw sewage and secondary influent. Since it was present in samples with good settling characteristics as well as in samples with poor settling characteristics it apparently does not form filaments long enough to interfere with the settling of the sludge.

A second filamentous bacterium was observed in both the air and Marox mixed liquor samples during January and in the air mixed liquor but not the Marox mixed liquor samples in February and March. It was not seen in the June samples. It is less than one micrometer in diameter and forms very long, straight filaments. It gave a negative sulfur deposition test but a lysozyme-detergent test showed some sheath material. It would grow some on GPY agar but died out after about one week. Good growth was obtained on initial isolation plates by adding calcium carbonate to the medium. In a GPY broth it lowered the pH to 3.0 in less than one day and then died off. It appears to be an acid producing relative of Sphaerotilus. It also appears to be the filamentous organism responsible for the high SVI values found in the mixed liquor samples last winter.

Fungus

The fungus colony counts on the raw sewage, secondary influent, and mixed liquor samples were higher than is usual for sewage and activated sludge. Also, an unusually high proportion of fungi which produce either arthrospores or blastospores were found. However, the fungus counts were approximately one tenth of the fungus counts I have found in mixed liquor when it was clear that the fungi were growing in the system and interfering with the settling characteristics of the sludge.

Actinomycetes

Actinomycete colony counts were in the normal range for sewage and mixed liquor samples except for the Marox pilot plant sample of February 23. That sample showed a mixed liquor consisting largely of actinomycetes. Otherwise there was no indication that the actinomycetes were causing a continuing problem in either system.

Conclusion

A variety of different types of filamentous organisms are present in both activated sludge systems. Most of the filamentous organisms are present in the raw sewage and in the secondary influent as well as in the mixed liquor. The fungi may be partially responsible for the poor flocculation observed but are not present in high enough numbers to interfere with the settling characteristics of the sludge. Actinomycetes could cause settling problems if a long sludge residence time were used but this is not usually the case. The filamentous bacteria present appear to be microaerophylic and appear to grow more vigorously in the air system than in the oxygen system. The filamentous bacterium which appears to be the most likely cause of high SVI values is an acid-producing, sheathed organism which has not been previously described.